Design Heard: Interpretations of the Design Process

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Dharma Dailey
With special guests:
Sound Improv Live!
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Design Heard: Interpretations of the Design Process

Part 1: Capturing and Describing Design Processes

Part 2: Representing Design Processes

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Many Collaborators…

- Collaborators, co-authors, and research team members include Robin Adams, Arif Ahmer, Brad Arneson, Theresa Barker, Maria Buan, 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, Aaron Joya, Allison Kang, Deborah Kilgore, Kristina Krause, Vipin Kumar, Alex Lew, Terri Lovins, Stefanie Lozito, Janet McDonnell, Annegrete Mølhave, Andrew Morozov, Susan Mosborg, Carie Mullins, Heather Nachtmann, Wai Ho Ng, Will Richey, Eddie Rhone, Axel Roesler, Wendy Roldan, Jason Saleem, Giovanna Scalone, Kathryn Shroyer, Elvia Sierra-Badillo, Roy Sunarso, Steve Tanimoto, Jennifer Turns, Cheryl Wang, Ken Yasuhara, and Mark Zachry…
- …and over 75 additional undergraduate students

Doing Design: A Human Endeavor

- Who designs?
  - "Everyone designs who devises courses of action aimed at changing existing situations into preferred ones" (Simon, 1969)
  - Going from state "A" to state "B"
  - To solve a problem, satisfy a need

- Who designs?
  - Architects, authors, engineers, chefs, musicians, landscape architects...
  - All of us

Design Process:
Going from state "A" to state "B"

- Examples
  - Improv performers
    - Prompt - > performance
  - Landscape architects
    - Empty yard - > garden
  - Chefs, moms, dads…
    - Empty plate - > dinner
  - Author
    - Blank page - > poem

Design Process: Going from state "A" to state "B"

- Engineering examples
  - Improve human health - > MRI machines, heart valves, etc.
  - Need to go from one side of a river to another -> ferry system, bridge, etc.
  - Desire to explore -> space program
  - Deal with pests in garden -> pesticide
- Possibility of unintended consequences
  - DDT (pesticide)
  - Hole in ozone (refrigeration, aerosols)
  - Failure of early heart valves
  - Bridge failures

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A research program…

- Engineering is “design under constraint” (Bill Wulf, 1998)
- My research program – to understand how engineers design
  - Understand design expertise
- With the long term goal to figure out how to teach engineering students about the importance of understanding context

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Examining Design Expertise: A Research Study

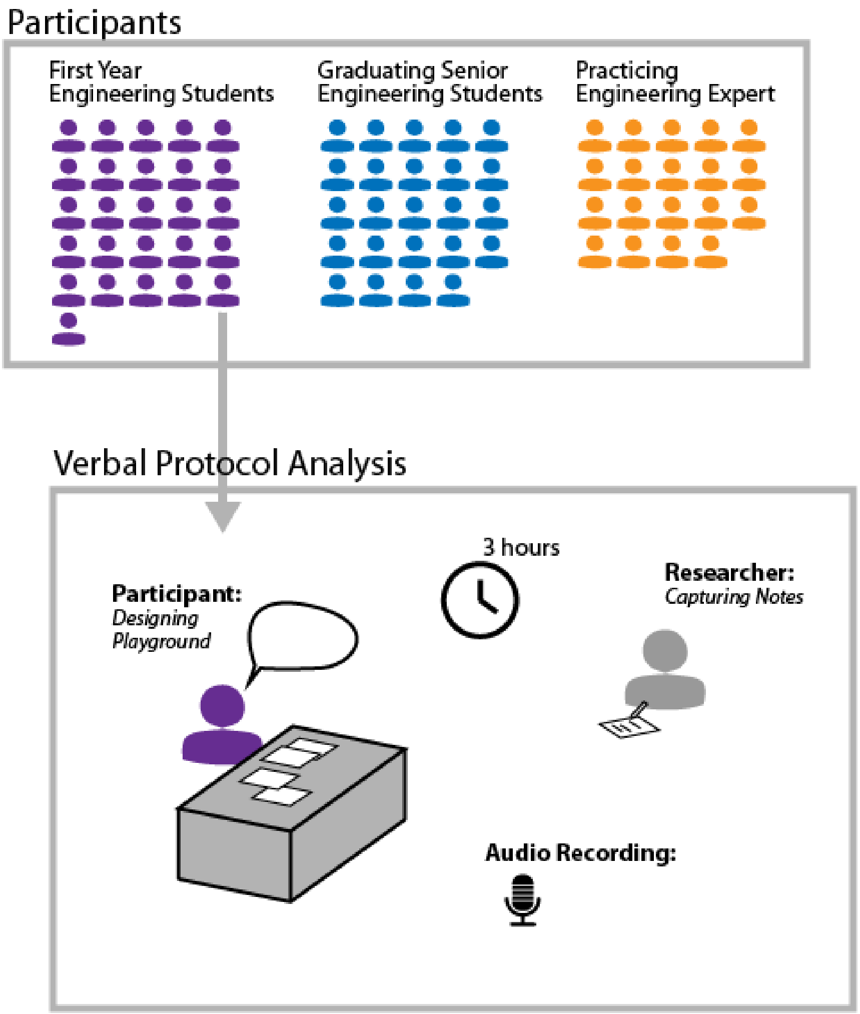
- Task
  - Design a playground for a fictitious neighborhood
- Participants
  - First-year engineering students (*n* = 26)
  - Graduating senior engineering students (*n* = 24)
  - Practicing engineering experts (*n* = 19)
- Verbal protocol analysis
  - Individuals had up to 3 hours in a lab setting
  - Think-aloud protocol
  - Segment and code transcripts with design process codes

Problem statement: Design a playground

- Subject to a set of constraints
  - 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.
  - Must be safe for the children,
  - Must remain outside all year long,
  - Must not cost too much,
  - Must comply with the Americans with Disabilities Act.
- Your design should use materials that are available at any hardware or lumber store.
- The playground must be ready for use in 2 months.

Why a playground?

Examining Design Expertise: A Research Study



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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

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Defining design: Design process activities
Derived from analysis of 7 engineering texts

Design Activities	Transcript Examples
(Identification of a Need)	
Problem Definition	"Any equipment you design must be safe for the childre
Information Gathering	"Hmmm do you have, a list of materials"
Generation of Ideas	"Trying to think what should be more sturdy."
Modeling	"I won't need supports in the middle, but I'll need …
Feasibility of analysis	"ok, so.. around two thousand dollars left."
Evaluation	"not softwood, hardwood is too expensive."
Decision	"I think we should...use galvanized steel."
Communication	Ok. I'm just making instructions...
(Implementation)	

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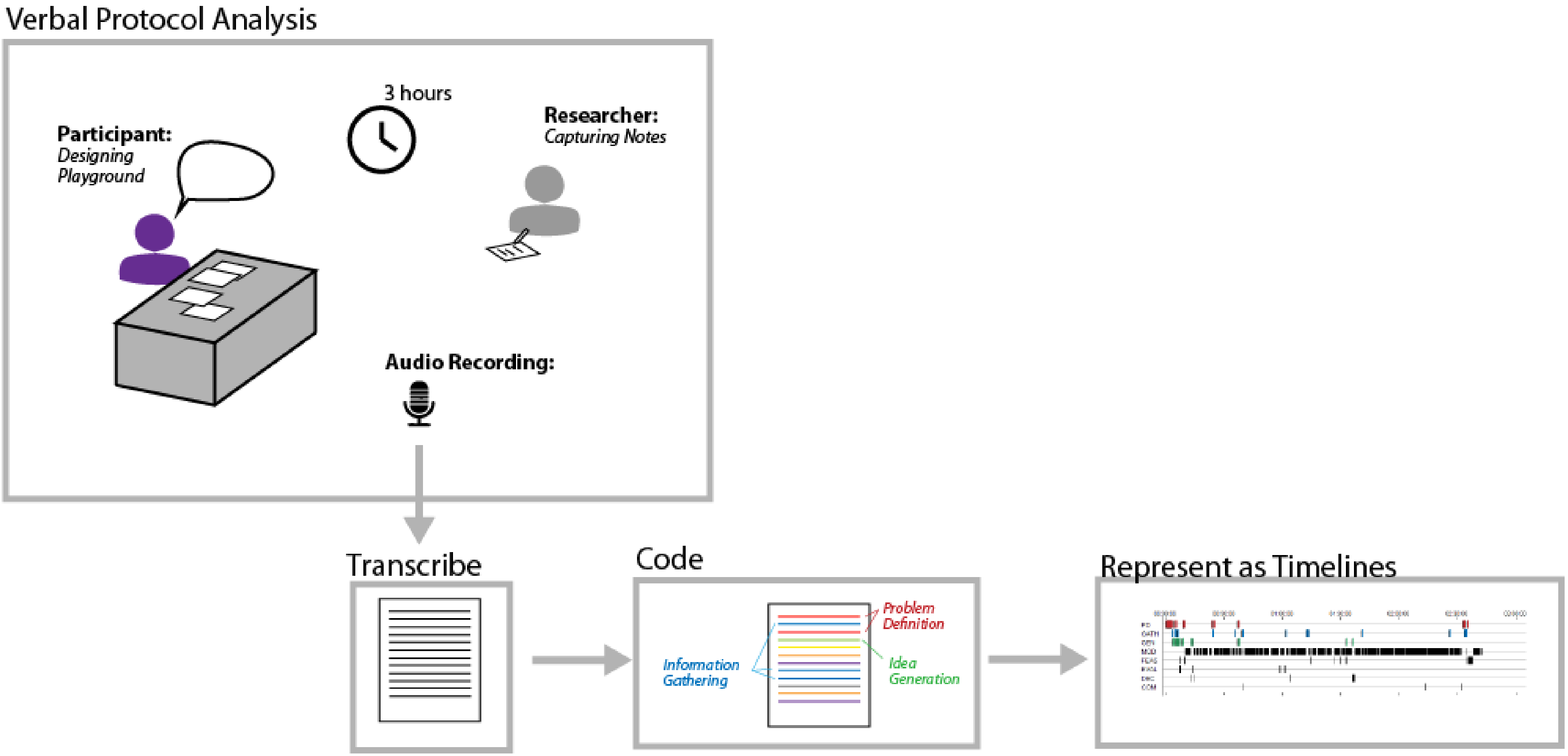
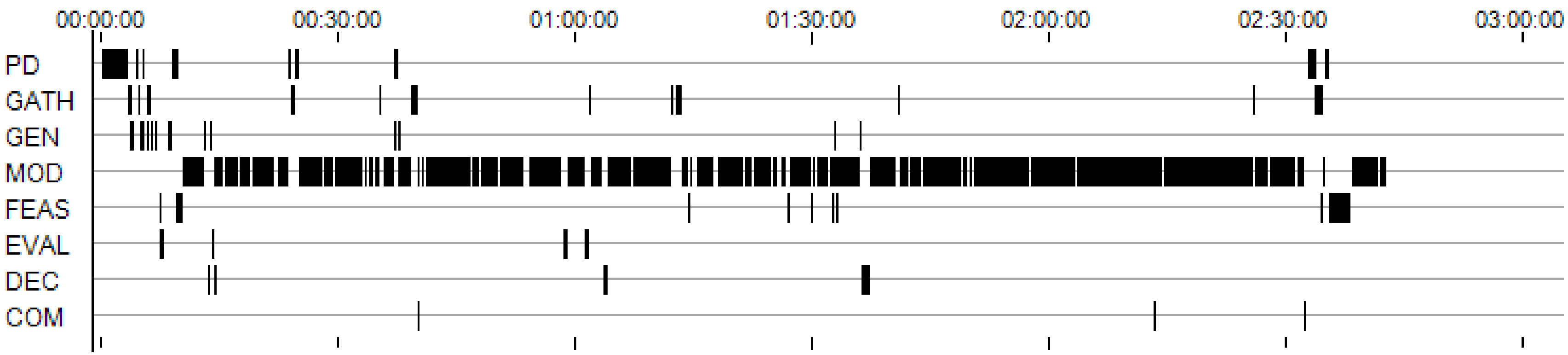
Examining Design Expertise: A Research Study



A design process timeline

First-Year (Quality Score = 0.45)



PD:	Problem Definition	FEAS:	Feasibility Analysis
GATH:	Gathering Information	EVAL:	Evaluation
GEN:	Generating Ideas	DEC:	Decision Making
MOD:	Modeling	COM:	Communication

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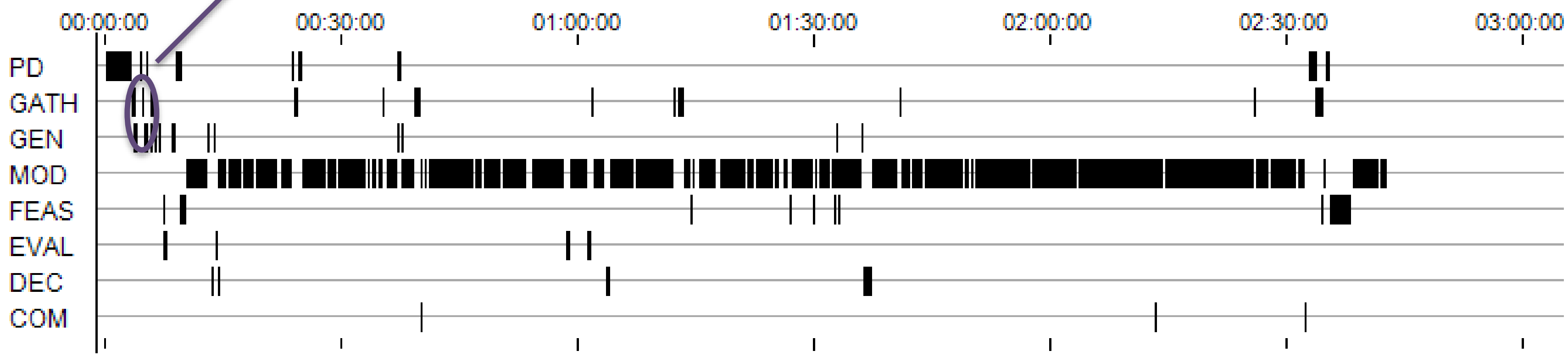
A design process timeline – gather info

"Hmmm do you have, a list of materials"

First-Year (Quality Score = 0.45)



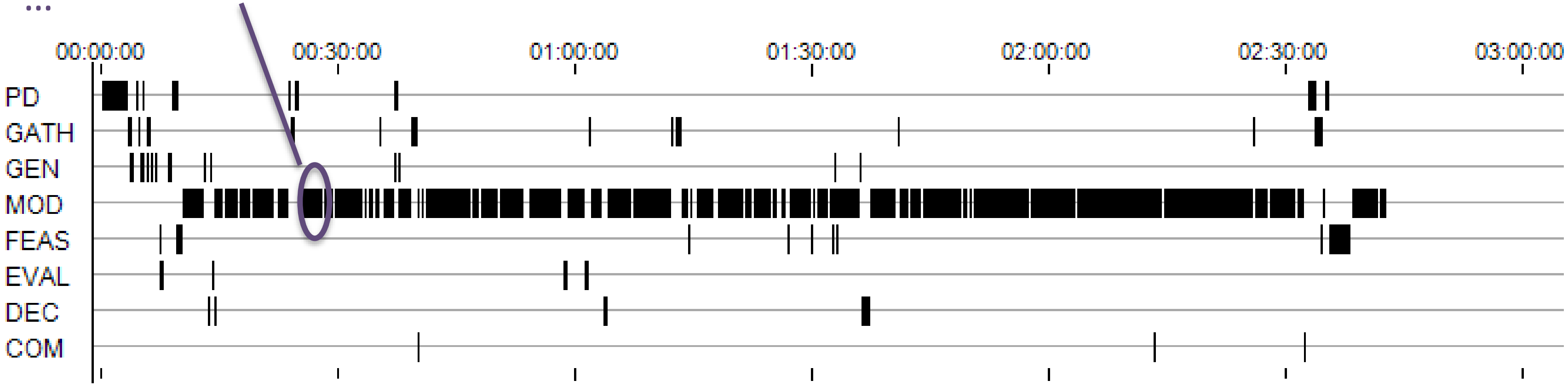
PD: Problem Definition
GATH: Gathering Information
GEN: Generating Ideas
MOD: Modeling

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

A design process timeline - modeling

"I won't need supports in the middle, but I'll need …

First-Year (Quality Score = 0.45)



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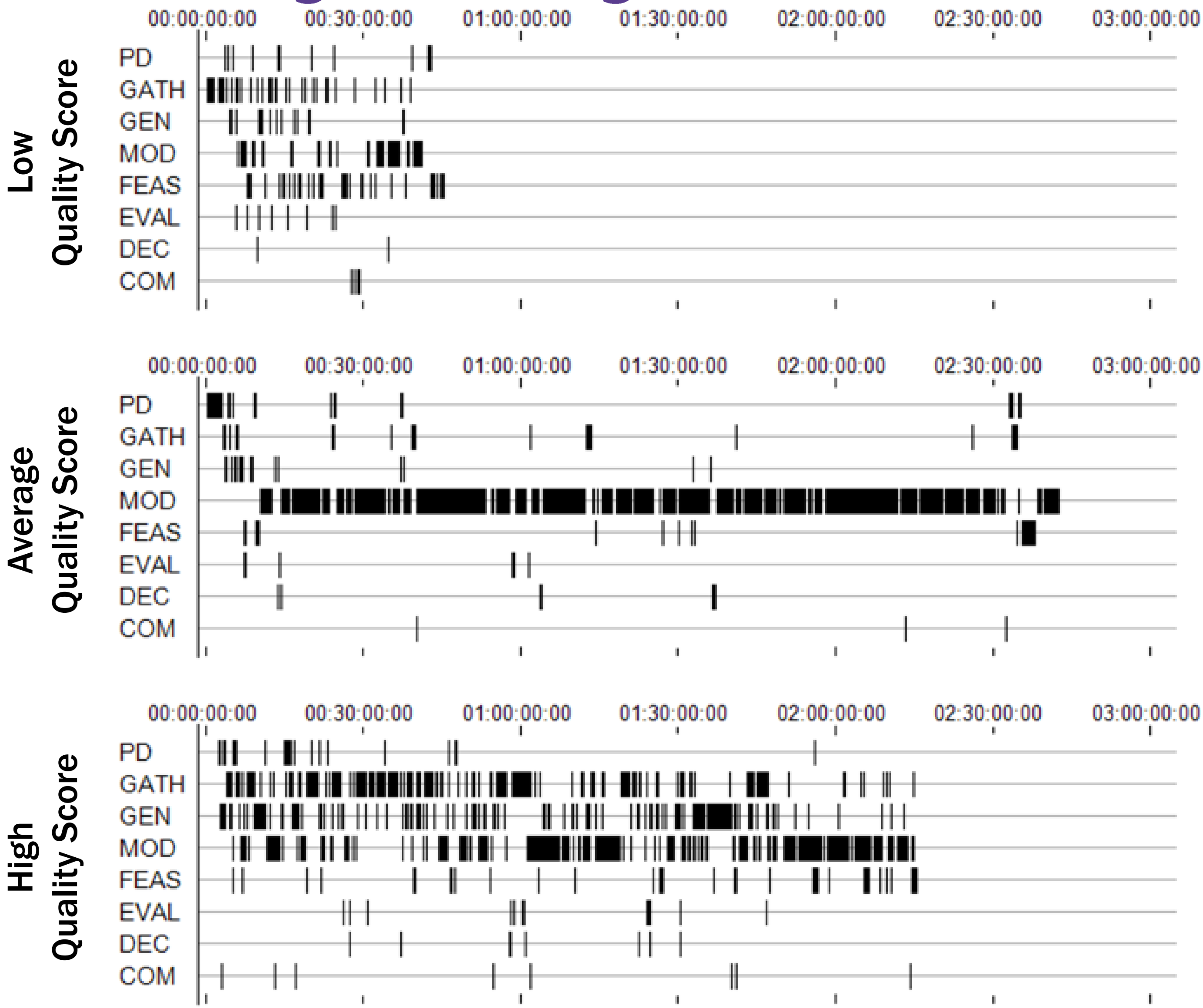
First-Year engineering students



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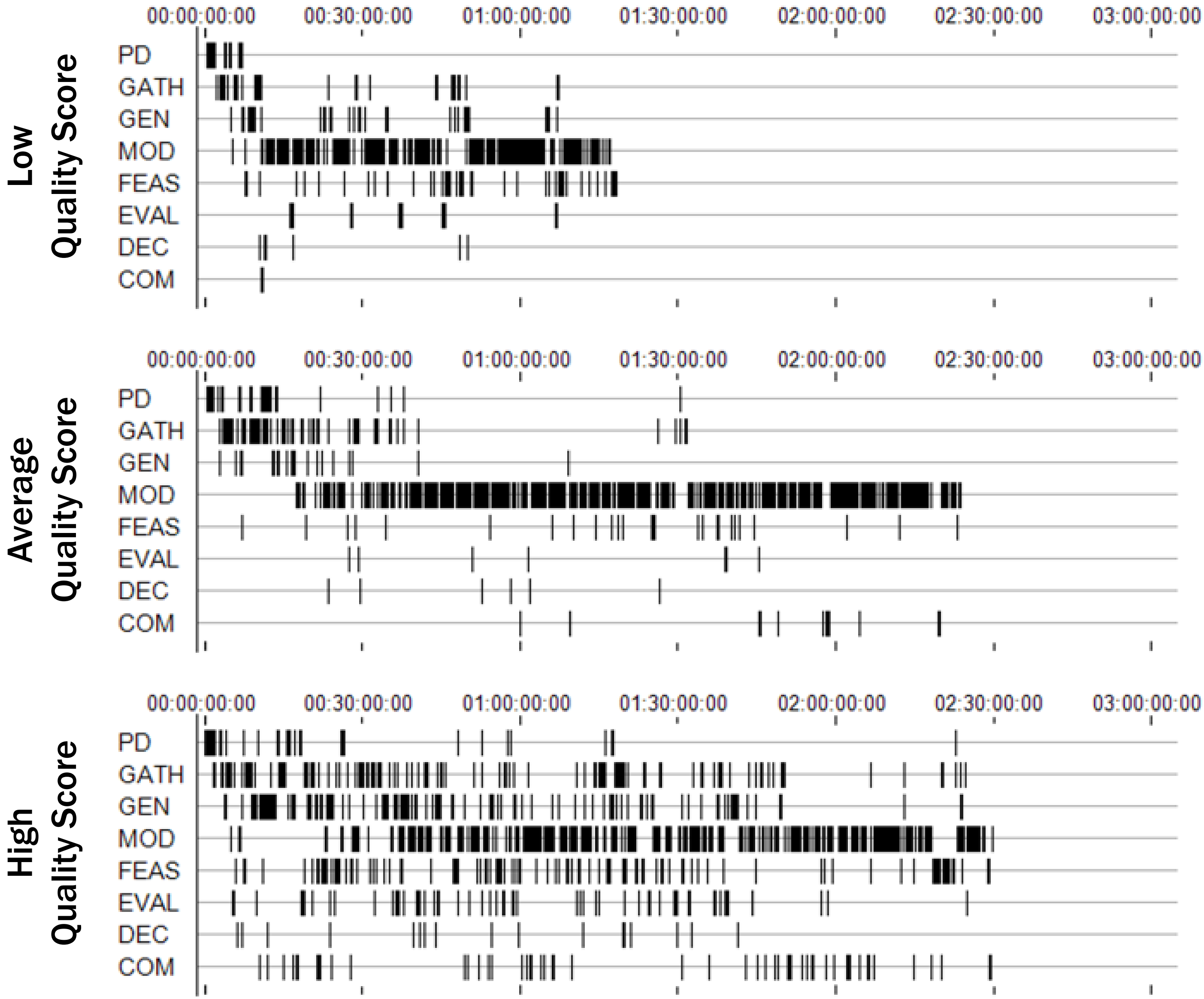
Graduating engineering students



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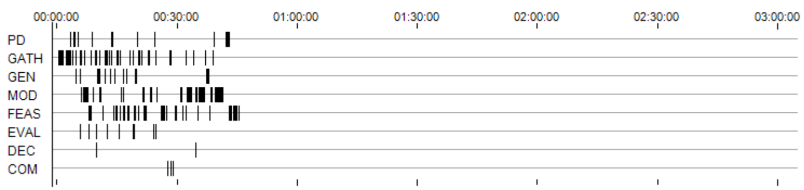
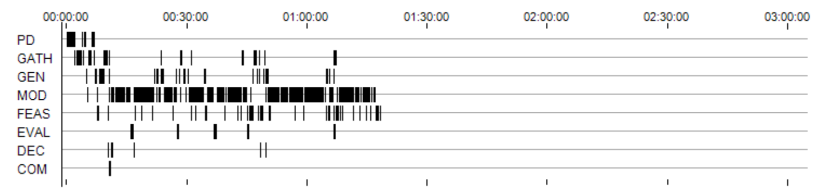
What do you see?

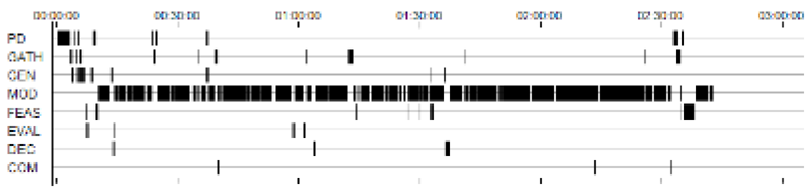
First-Year #1 [Low Quality Score (37)]



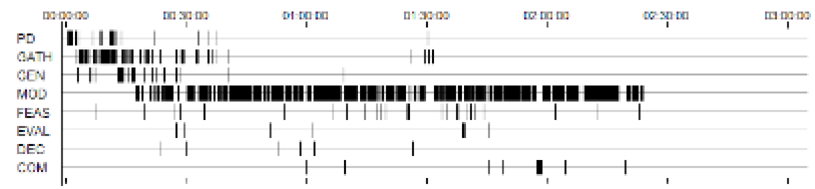
Graduating Senior #1 [Low Quality Score (38)]



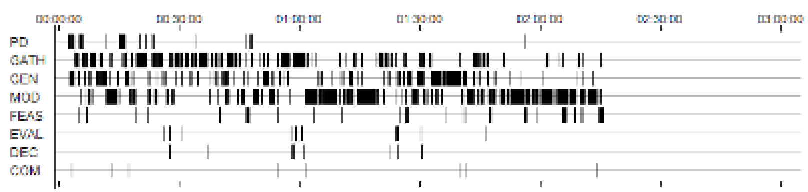
First-Year #2 [Average Quality Score (45)]



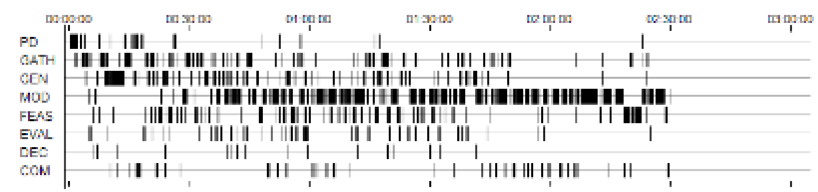
Graduating Senior #2 [Average Quality Score (53)]



First-Year #3 [High Quality Score (62)]



Graduating Senior #3 [High Quality Score (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?

Design Timelines Activity

- Work with a partner to explore the following
- In the design process timelines shown on the first page:
  - What similarities and differences do you see between the first year and graduating senior engineering students?
  - Do these similarities or differences also involve the quality scores? How so?

Design process 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 activities.
  - progress farther in the design process.
- (These differences are statistically significant.)

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

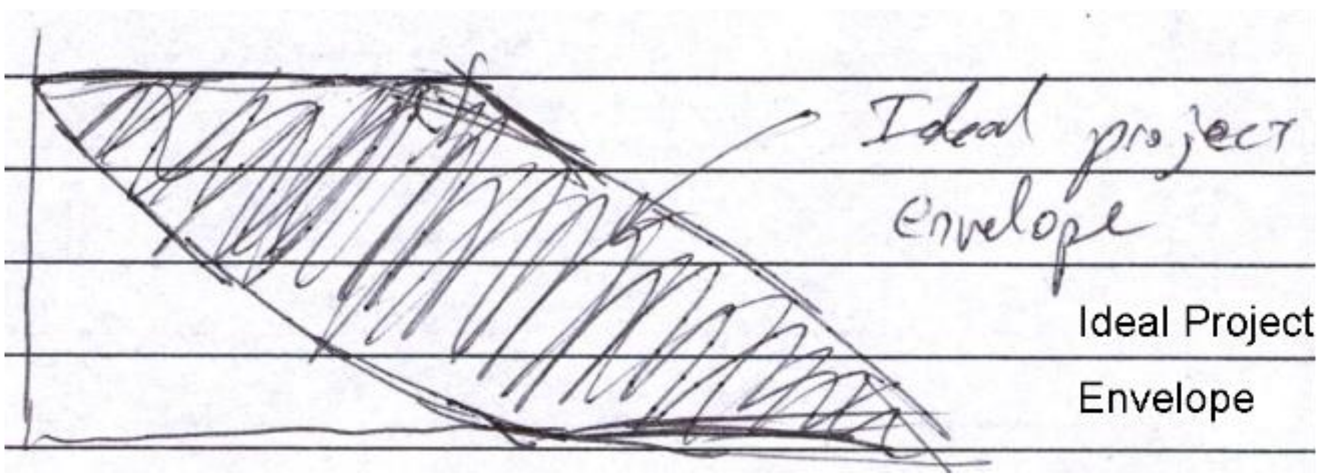
Selected student insights

- "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."

(Borgford-Parnell, Deibel & Atman, 2010)

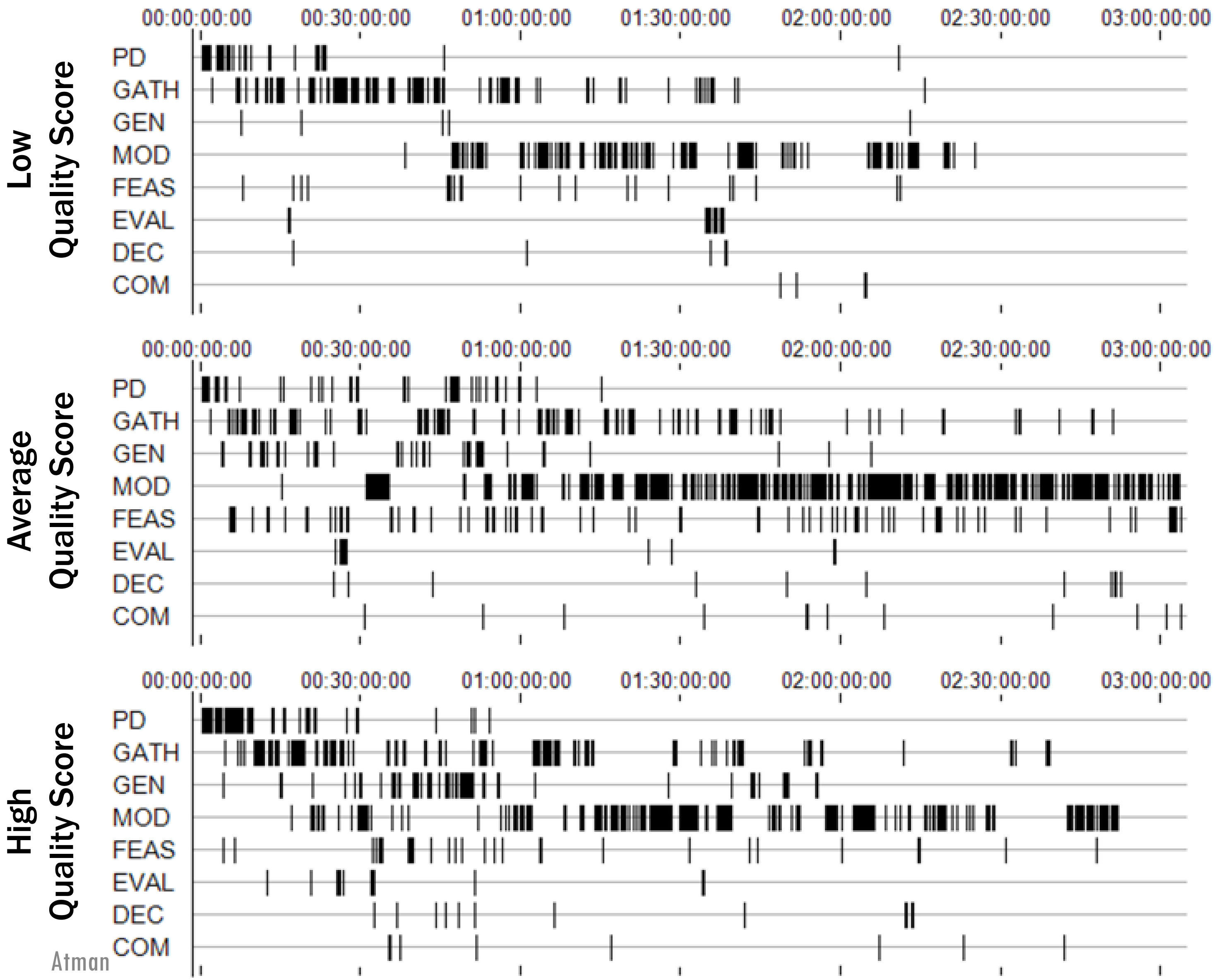
Selected student insights

Graduating Senior (Quality Score = 0.63)



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

Engineering experts



Atman

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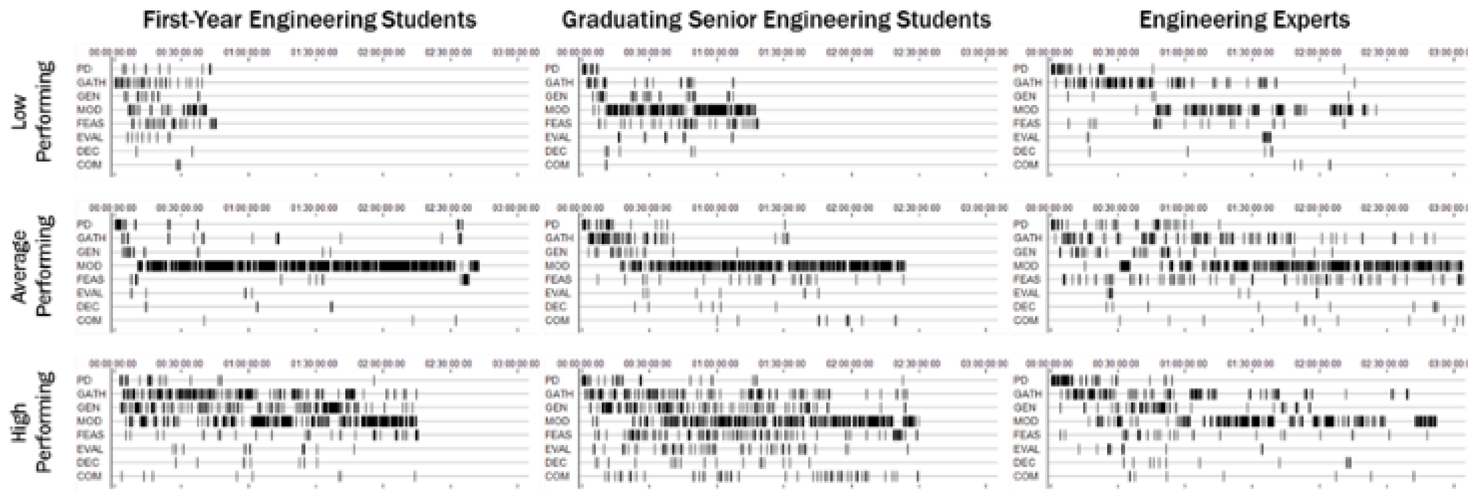
Examining engineering design models



- 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)

What should we teach about design processes?

- Spend enough time understanding the problem up front
  - Understand the problem context
  - Be intentional about problem framing
- Gather information throughout the process
- Revisit the problem definition throughout the process
- Use a broad set of design activities
- Iterate and transition among design activities
- Spend a sufficient time modelling
- Spend enough time to solve the problem

Design Heard: Interpretations of the Design Process

Part 1: Capturing and Describing Design Processes

Part 2: Representing Design Processes

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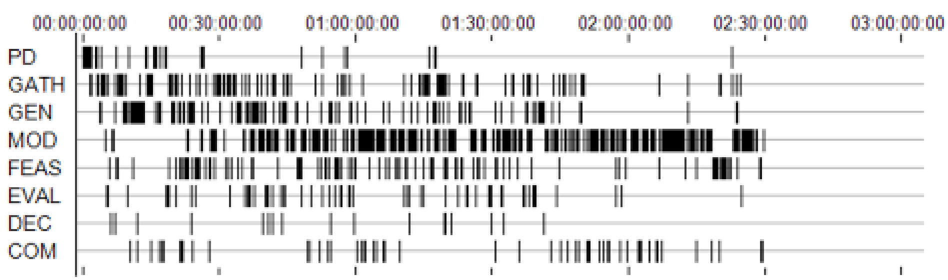
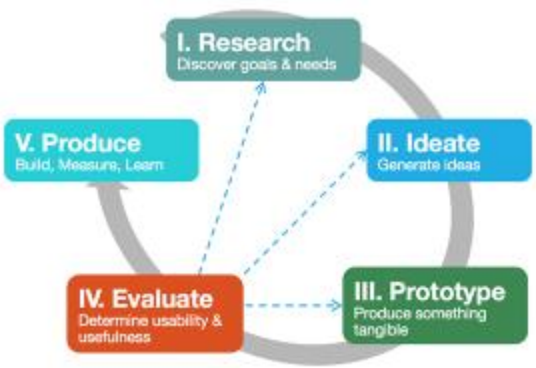
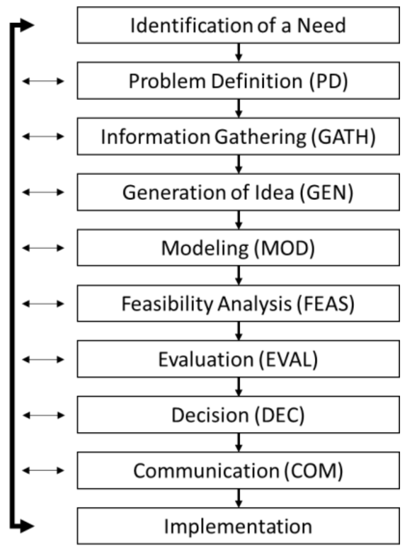
Design process representations







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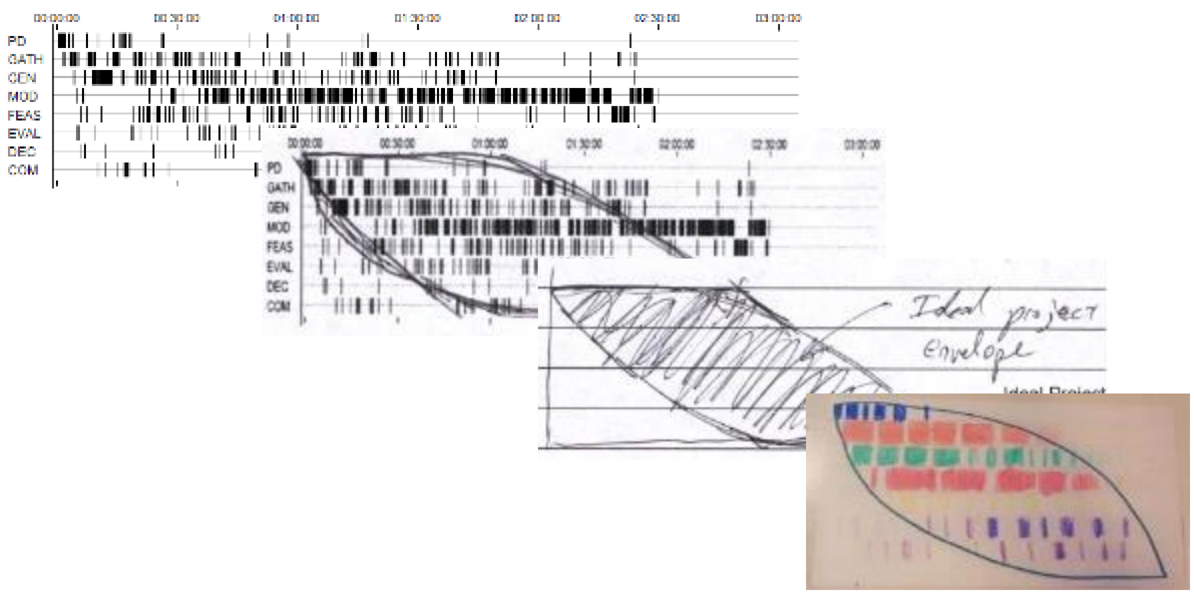
Once you see a timeline….



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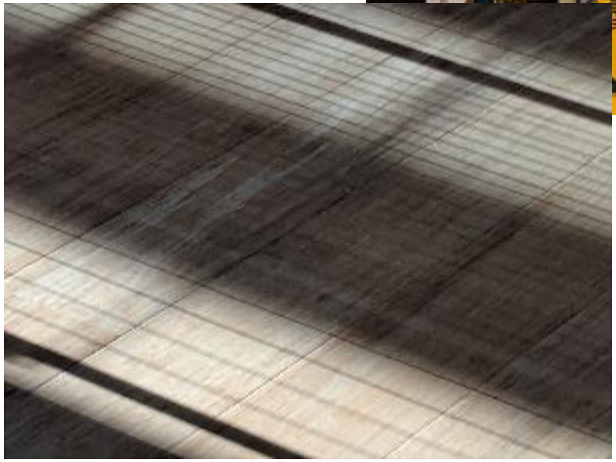
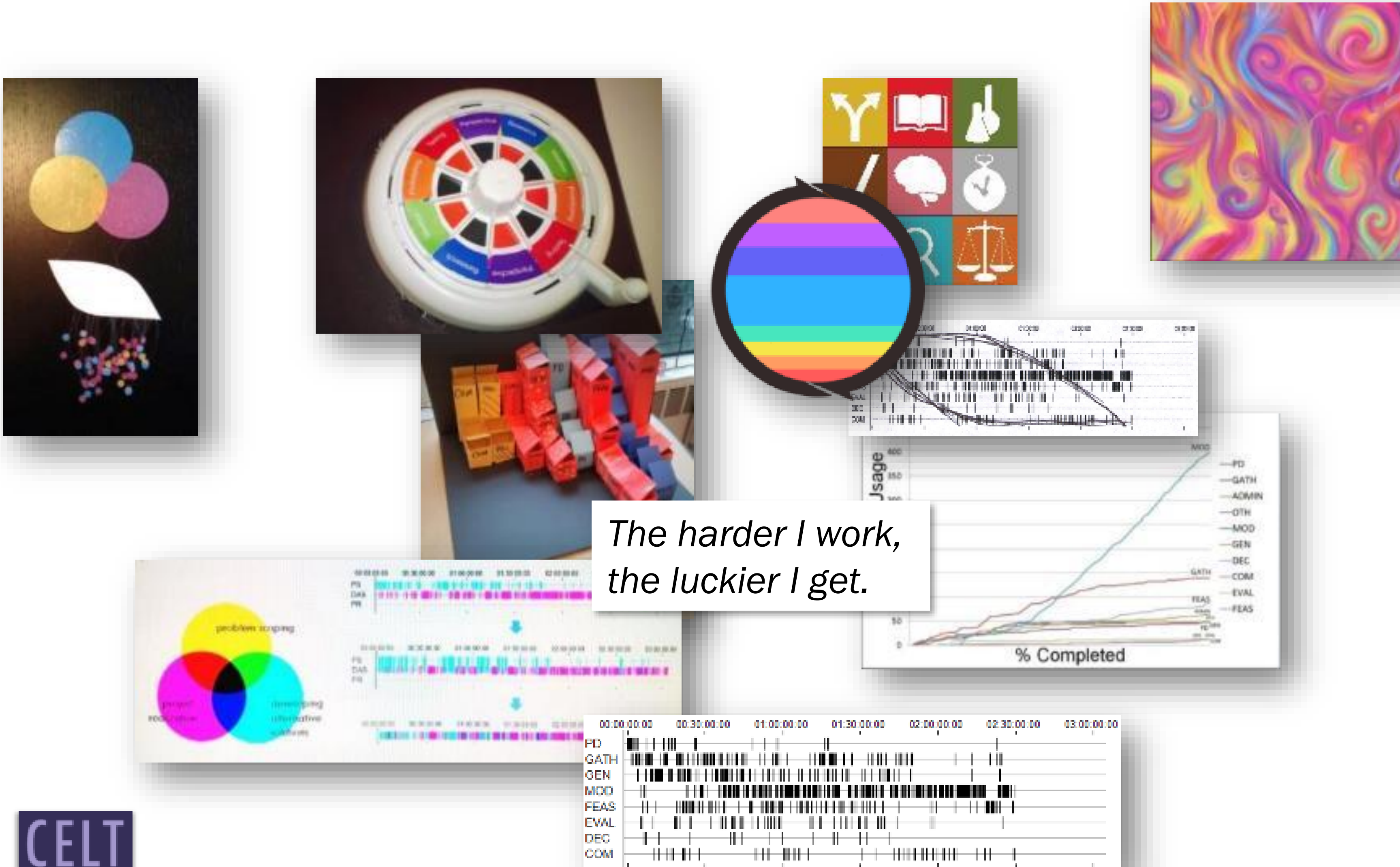
. . . you can see timelines everywhere!



Using Representations to Teach Design



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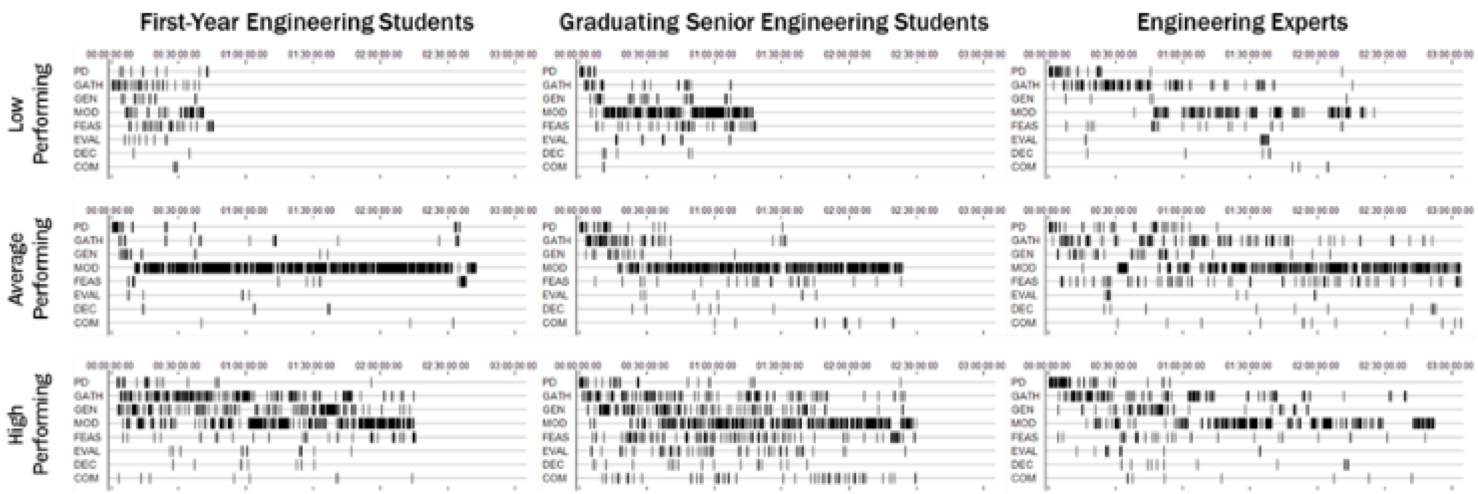
(McDonnell, & Atman, 2015; Atman et al., 2015)

Music??


First-Year Engineering Students
Graduating Senior Engineering Students
Engineering Experts
Low Performing
Average Performing
High Performing
PD
GATH
GEN
MOD
FEAS
EVAL
DEC
COM

What does design sound like?

Design soundtracks

Tonal Soundtrack: Original Senior C (927)

The Tonal version of design soundtracks is the most literal of all version. Each design activity is mapped to a specific pure tone on the pentatonic scale, with Problem Definition (PD) having the highest pitch. The start and stop of each tone is sharp and tightly tied to the underlying time-series data.

As with all design soundtracks, each activity's soun
separation is noted in the sound samples table to th

http://bit.ly/celtsoundtracks

Sound Mapping

- PD - Problem Definition
  E6 Tone (left ear)
- GATH - Gathering Information
  D6 Tone (right ear)
- A4 Tone (right ear)
- FEAS - Feasibility Analysis
  G4 Tone (left ear)
- EVAL - Evaluation
  E4 Tone (right ear)
- DEC - Decision Making
  D3 Tone (left ear)
- COM - Communication
  C3 Tone (right ear)

Return to Tonal Soundtrack Selection Page
Return to Design Soundtrack Index Page

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Jazz teacher perspectives

Clarence Acox

Bob Knatt

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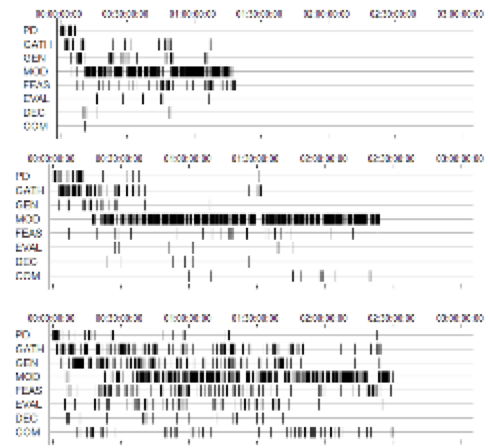
Jazz perspectives

- "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."



The blank signature, Magritte, 1965

Design Heard: Interpretations of the Design Process

Part 1: Capturing and Describing Design Processes

Part 2: Representing Design Processes

Part 3: Musical response by “Sound Improv Live!”

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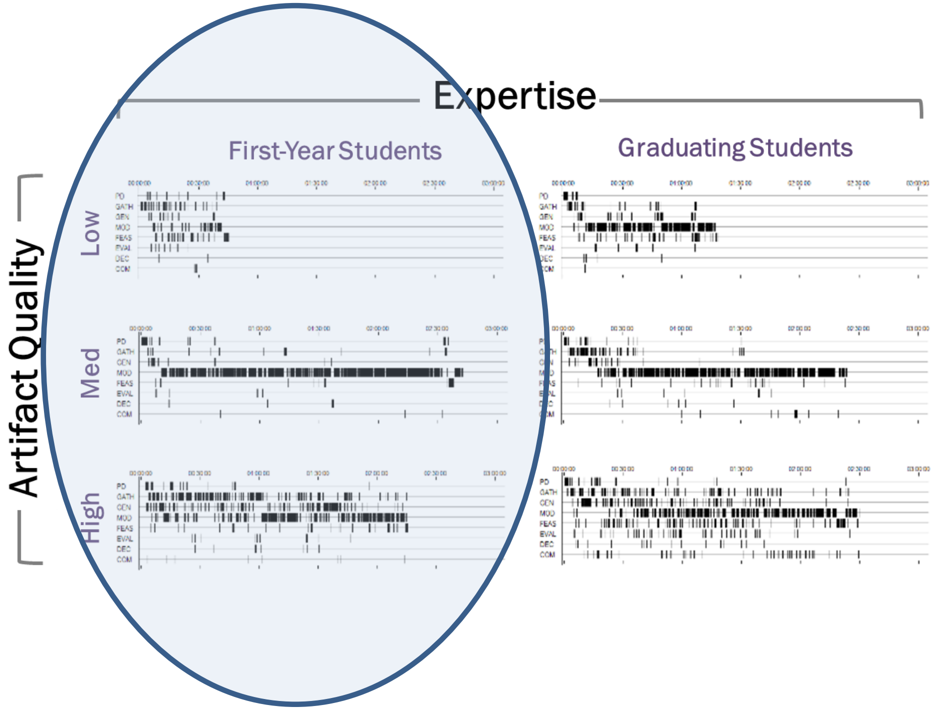
Musical Response by "Sound Improv Live!"

- After this brief introduction to design expertise research and timeline representations
- Improv singing group "Sound Improv Live!" explored interpretations of what they heard
- Here we hear their first impression response to several of the timelines
- Sound Improv Live! Members:
  - Van Calvez,Christine Castigliano, Dharma Dailey Chris Hille, Liz Kohlenberg,Thea LaCross, Marline Lesh, Cindy Pickreign, Sherry Serra, Debby Boland Watt

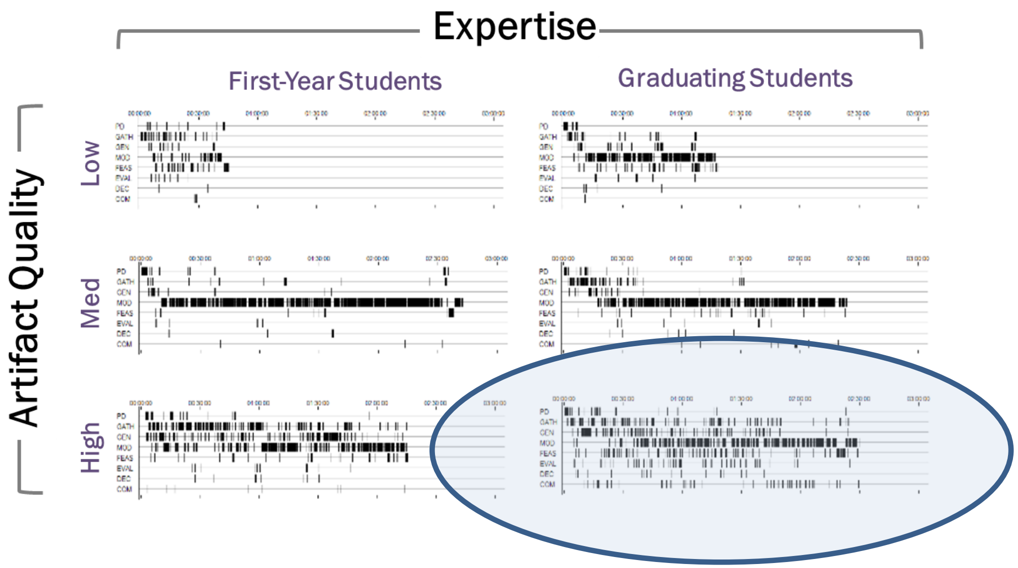
Musical Response by "Sound Improv Live!"

- First we hear a more literal response to timeline representations of three first-year students; with low, average and high artifact quality



Musical Response by "Sound Improv Live!"

- Next we hear a more abstract response, expressing the layered, nuanced and complex interaction that a design process can aspire to



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More information about this work

- **Design Teaching/Learning**
  - Atman, C.J., Arif, A., Shroyer, K.E., Turns, J.A., & Borgford-Parnell, J. (2016) “Spend another day in our class talking about this research please”: Student insights from a research-based design thinking exercise. Design Research Society, 2016 Design Research Society 50th Anniversary Conference (DRS), Brighton, UK. June 27-30, 2016.
  - Atman, C.J., McDonnell, J., Campbell, R., Borgford-Parnell, J., & Turns, J. A. (2015). *Using design process timelines to teach design: Implementing research results*. American Society of Engineering Education Annual Conference (ASEE). Seattle, WA. June 14-17, 2015.
  - McDonnell, J. & Atman, C.J. (2015). *Paying attention to the design process: Critically examining personal design practice.* LearnxDesign Conference. Chicago, IL. June 28-30, 2015.
  - Borgford-Parnell, J., Deibel, K., & Atman, C. J. (2010). From engineering design research to engineering pedagogy: Bringing research results directly to the students. *International Journal of Engineering Education, 26*(4), 748–759.
- **Design Expertise**
  - Atman, C. J., Adams, R. S., Cardella, M. E., Turns, J., Mosborg, S., & Saleem, J. (2007). Engineering design processes: A comparison of students and expert practitioners. *Journal of Engineering Education, 96*(4), 359–379.
  - Atman, C. J., Chimka, J. R., Bursic, K. M., & Nachtmann, H. L. (1999). A comparison of freshman and senior engineering design processes. *Design Studies, 20*(2), 131–152.
- **Design Process Representations**
  - Atman, C. J., Borgford-Parnell, J., Goist, Z., Deibel, K., Blair, J., Bodle, C., Kumar, V., Roesler, A., Tanimoto, S., & Zachry, M. (2010). Seeing and hearing design: Exploring how visual representations and sound tracks could be used to teach design. In *Proceedings of Design Thinking and Research Symposium 8* (pp. 25–37), Sydney, Australia, 2010.
  - Atman, C. J., Deibel, K., & Borgford-Parnell, J. (2009). The process of engineering design: A comparison of three representations. In *Proceedings of the International Conference on Engineering Design, Stanford University, 2009.*
- **Design Awareness**
  - Atman, C.J. (2018). *Design Awareness: Patterns, Pivots and Persistence.* Invited Talk to the International Conference on Transformations in Engineering Education – Imparting the Futuristic Skills (ICTIEE AP’ 18), July 15, 2018. SRM University - AP, Amaravati, India