Function Modeling: Pause Patterns

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CEDAR
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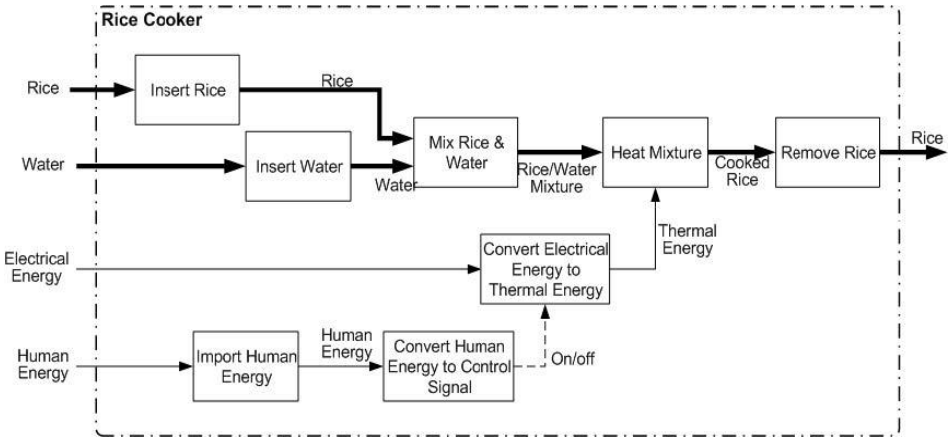
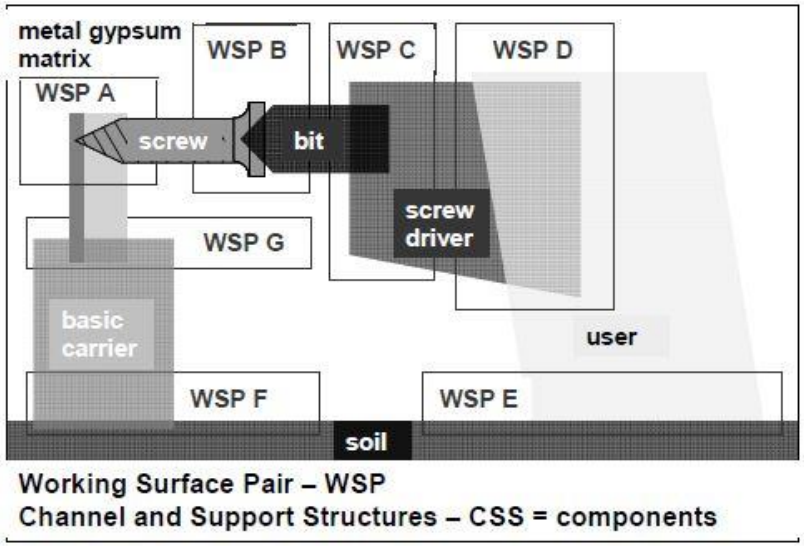
Background on Function Modeling

- Tool used in conceptual design stage
  - **Generative Design**
    - Relate problem space to solution space
    - Place boundaries on the design space
  - Reverse Engineering
    - Decompose product function
    - Identify excess in design
    - Trace product evolution
- Representations
  - Function-Behavior-Structure Models
  - Function-Behavior-State Model
  - **Function Structure Models**
  - Structure-Behavior-Function Models
  - Contact and Channel Model



Function Structure for rice cooker



Contact and Channel Model

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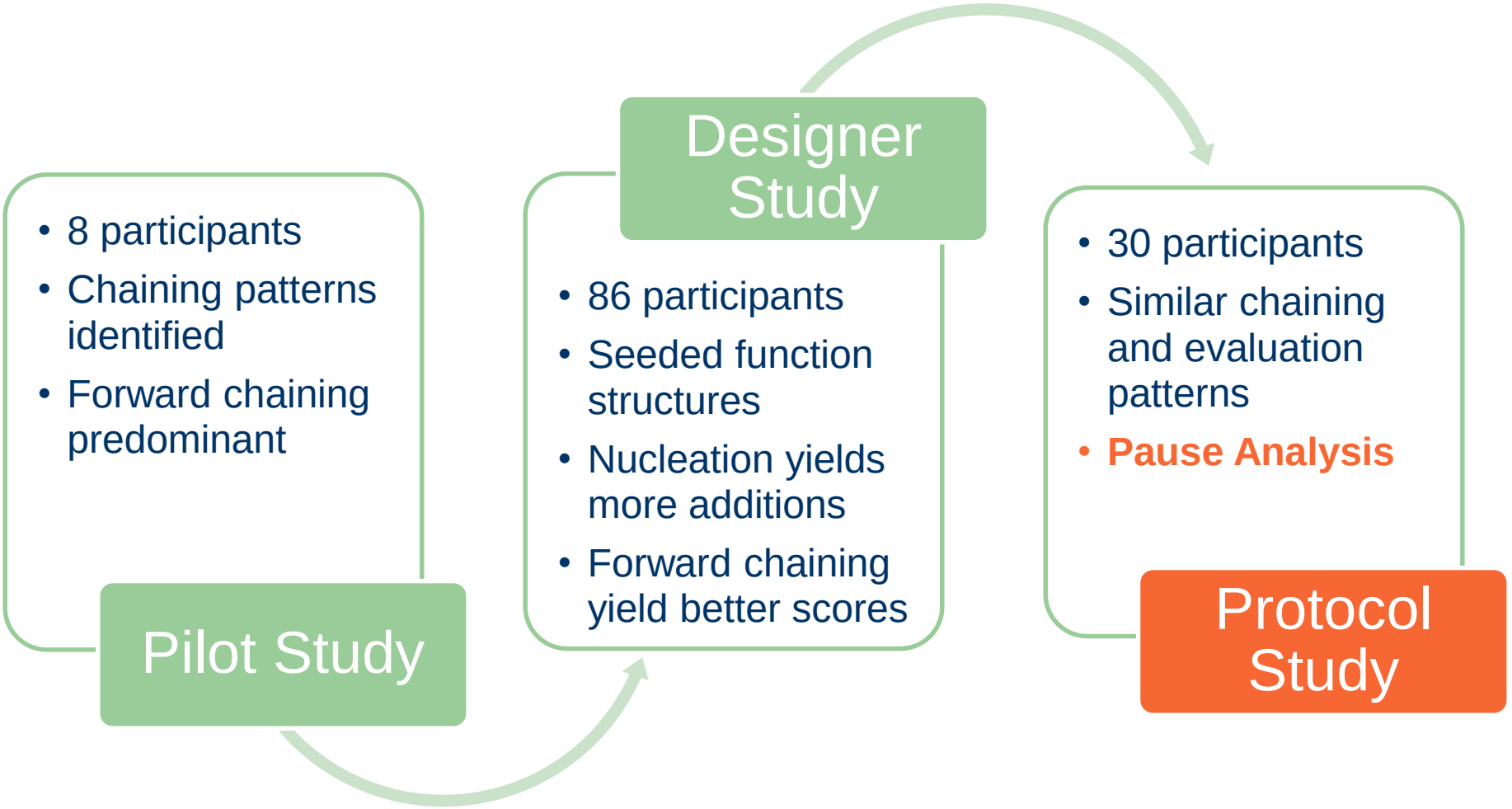
Previous Work on Modeling Behaviors



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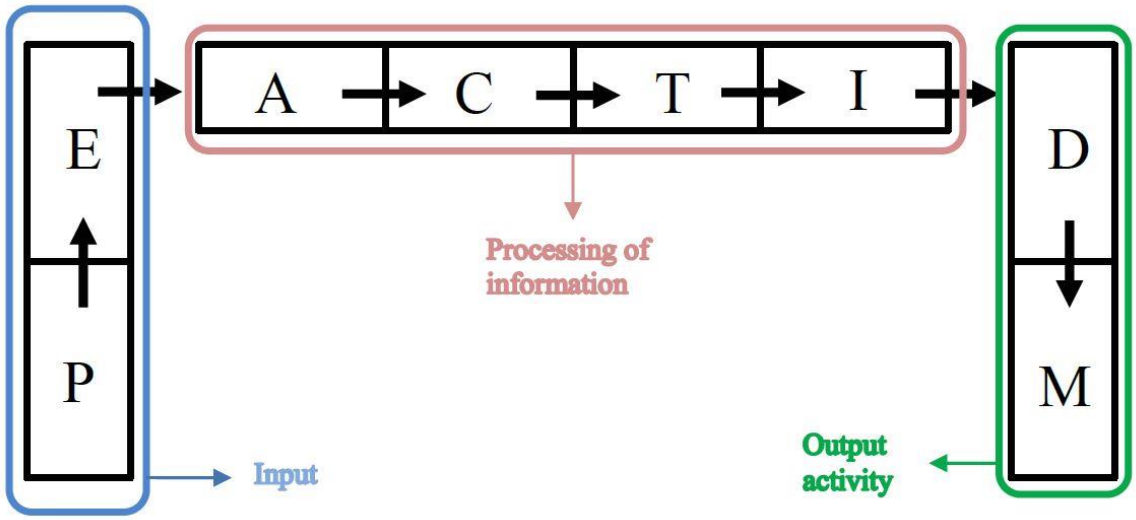
Cognitive Psychology Background



- Input from stimuli
  - Perceive and encode
- Information processing
  - Attend, comprehend, task and intend
  - Total time depends on preparation
- Output
  - Decode and move
- Time taken in processing corresponds to pause length
  - Suggests the amount of thought given

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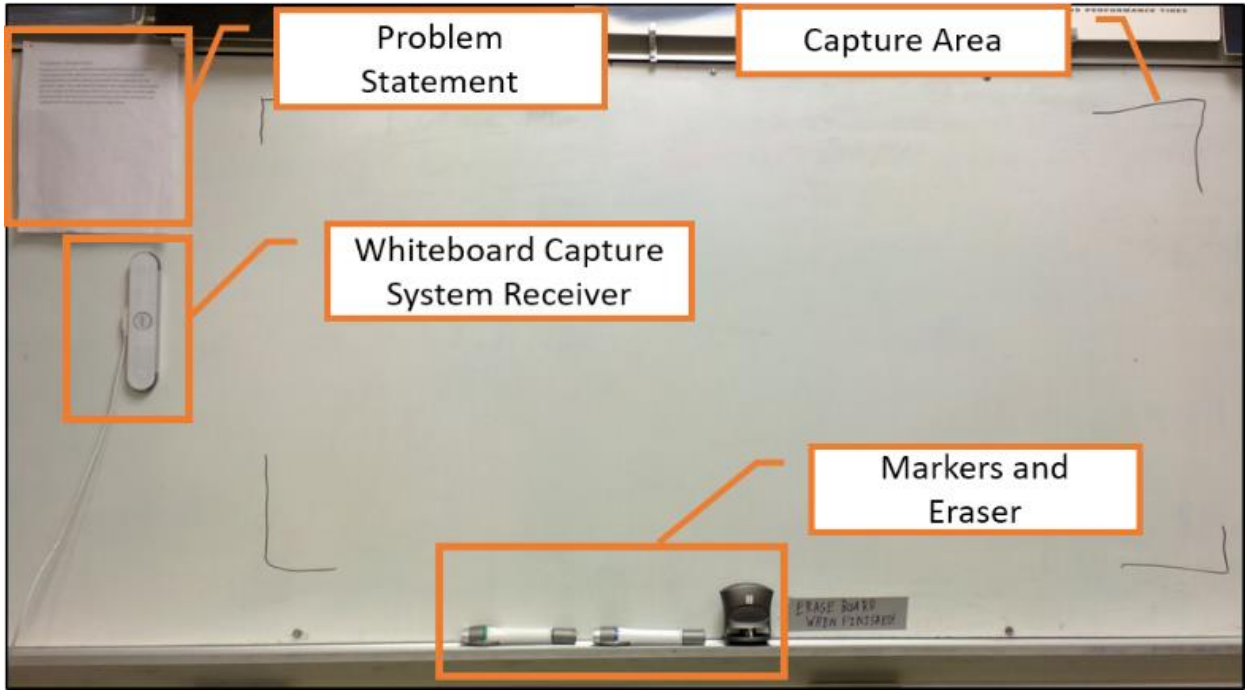
Protocol Study Setup



- Set in a closed meeting room
- Minimize distractions
- No time limits
  - 30 to 45 minutes expected
- Camera recording
- Whiteboard capture

- 22 students (ME senior design 1)
  - Familiar with function structures
  - Familiar with ironing and recycling
- Age group of 20 – 25 years
- Internship or Co-op experience

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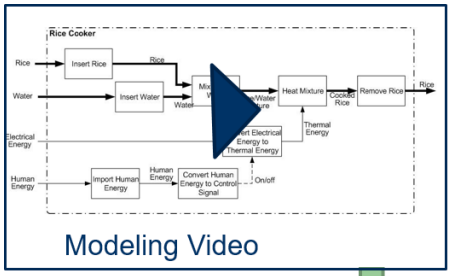
Data Collection and Coding

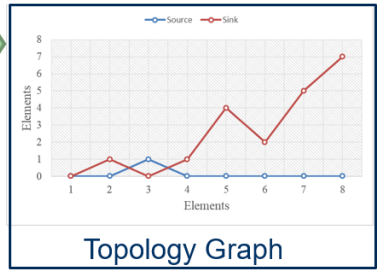
- Video recording from a 30 students
  - 22 undergraduate students
  - 8 graduate students (domestic and int'l)
- Element coding
  - Block, block text, edge, edge text, system boundary, and notes
- Activity coding
  - Add, delete, edit, pause, and read problem statement
- Topology coding



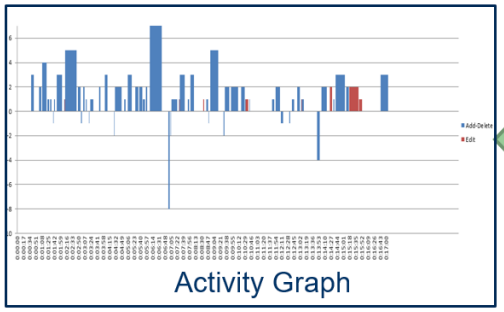
Modeling Video

Elem ID	Elem Typ	Topology	
1	N	0	0
2	B	1	
3	BT	0	1
4	E	3	
5	ET	1	0
6	ET	5	
7	E	0	1
8	ET	7	
9	ET	0	1
10	E	9	

Element Coding



Topology Graph


Activity Graph

Tm Stmp	n Stmp (Se	mp (Trunc	Act	Element IDs
0:00	0:00:00	0:00:00		
0:01	0:00:01	0:00:01	A	1 2 3
0:17	0:00:17	0:00:17		
0:26	0:02:10	0:02:10	A	4
0:30	0:00:30	0:00:30		
0:37	0:00:37	0:00:37	E	4
0:38	0:00:38	0:00:38		
0:40	0:00:40	0:00:40	A	5
0:43	0:00:43	0:00:43		
0:46	0:00:46	0:00:46	A	6
0:50	0:00:50	0:00:50		
0:56	0:00:56	0:00:56	PS	

Activity Coding

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Analysis of Pauses

- Pause length and frequency
  - Percent of activities as pauses
  - Percent of modeling time spent in pauses
- Distribution of pause lengths
  - Identify groupings of pauses
- Following the pauses
  - Distribution of activities after pauses
  - Distribution of elements after pauses

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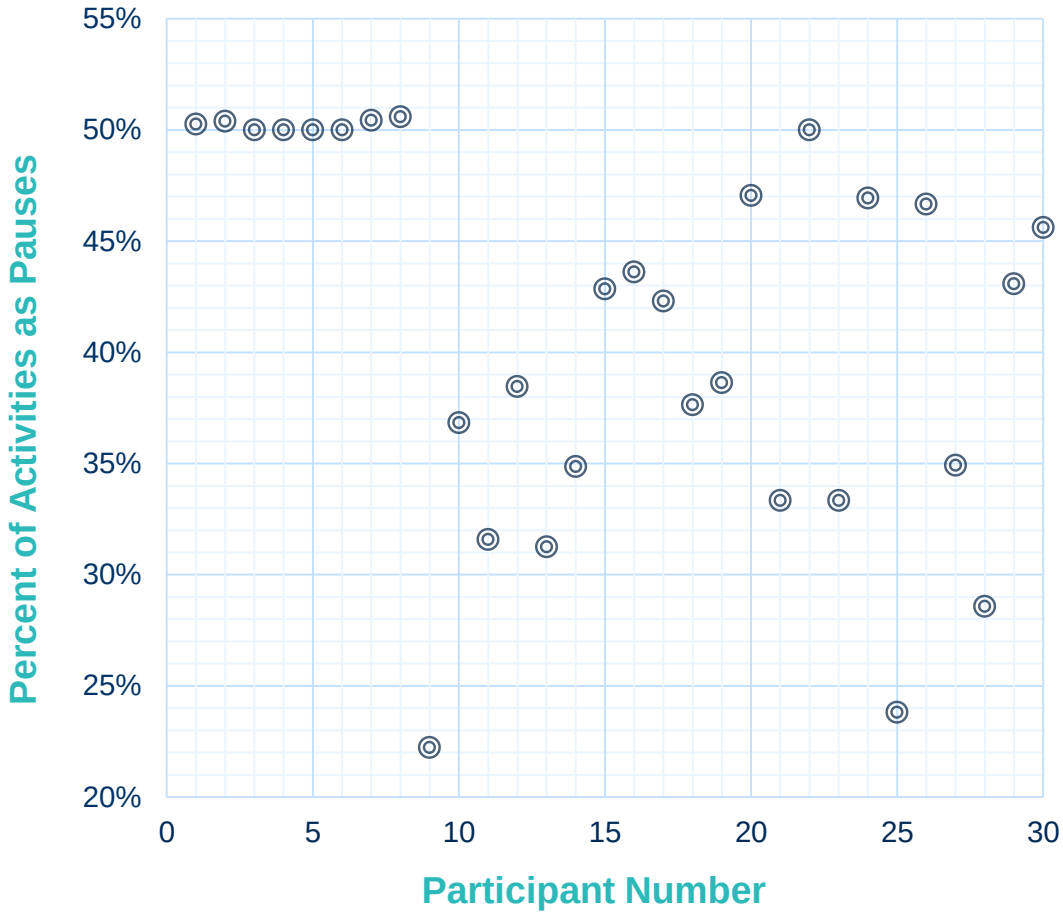
Results: Pause Frequency

- 50% of activities as pauses for Graduate Students
  - Suggests more deliberation
- Undergraduate students more distributed
  - Varying amounts of deliberation



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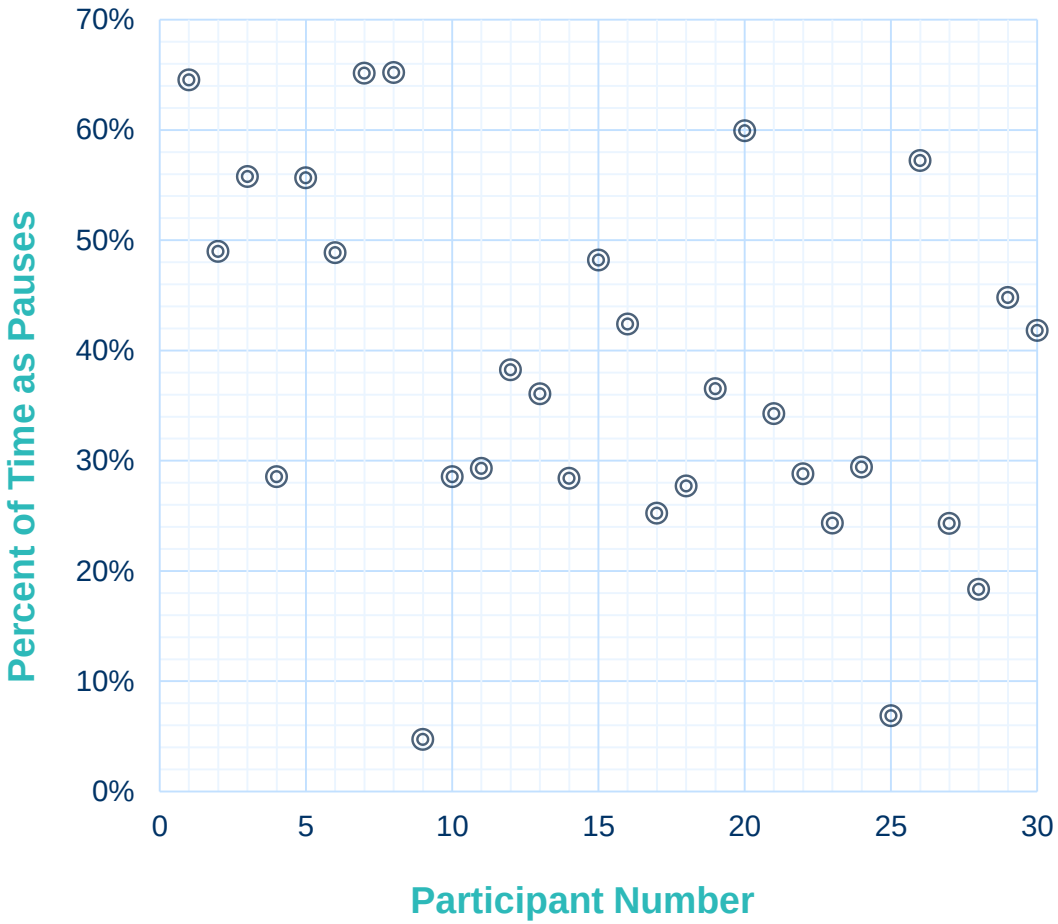
Results: Time Spent in Pauses

- Average time in pauses higher for graduate students
  - 54% graduate
  - 33% undergrad
- Most participants between 20% and 60%



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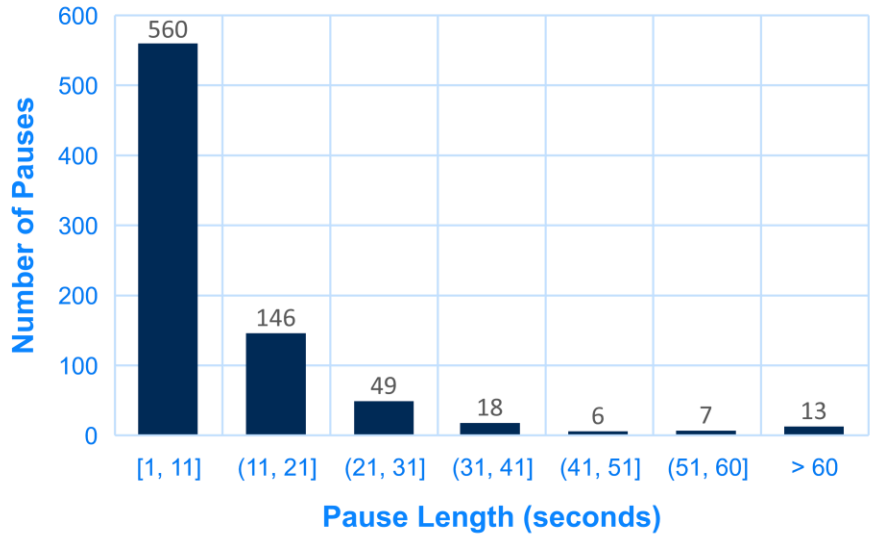
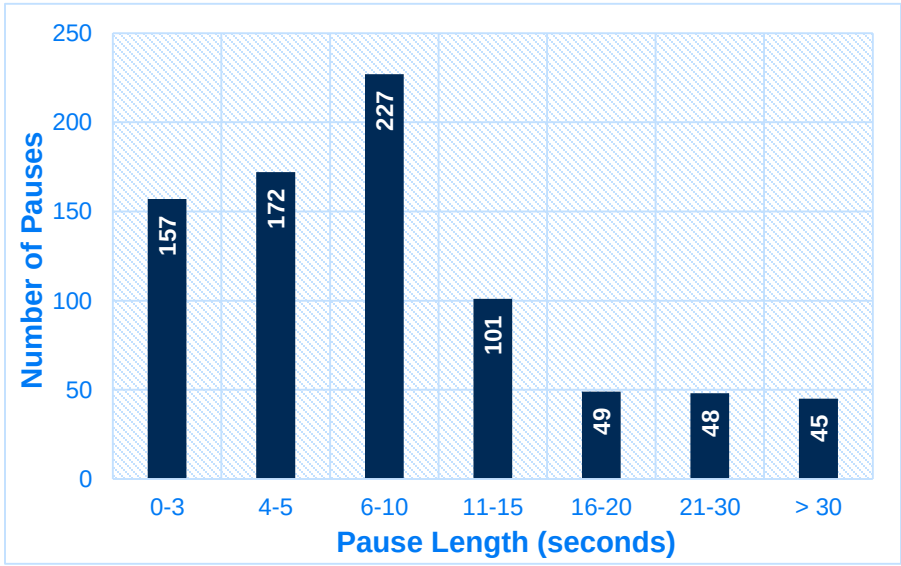
Distribution of Pause Lengths

- 799 pauses analyzed
- 95% of pauses ≤ 30s
  - 70% of pauses ≤10s
- Categorized pauses into three groups
  - Short pauses (0s – 5s)
  - Intermediate pauses (6s – 10s)
  - Long pauses (>10s)





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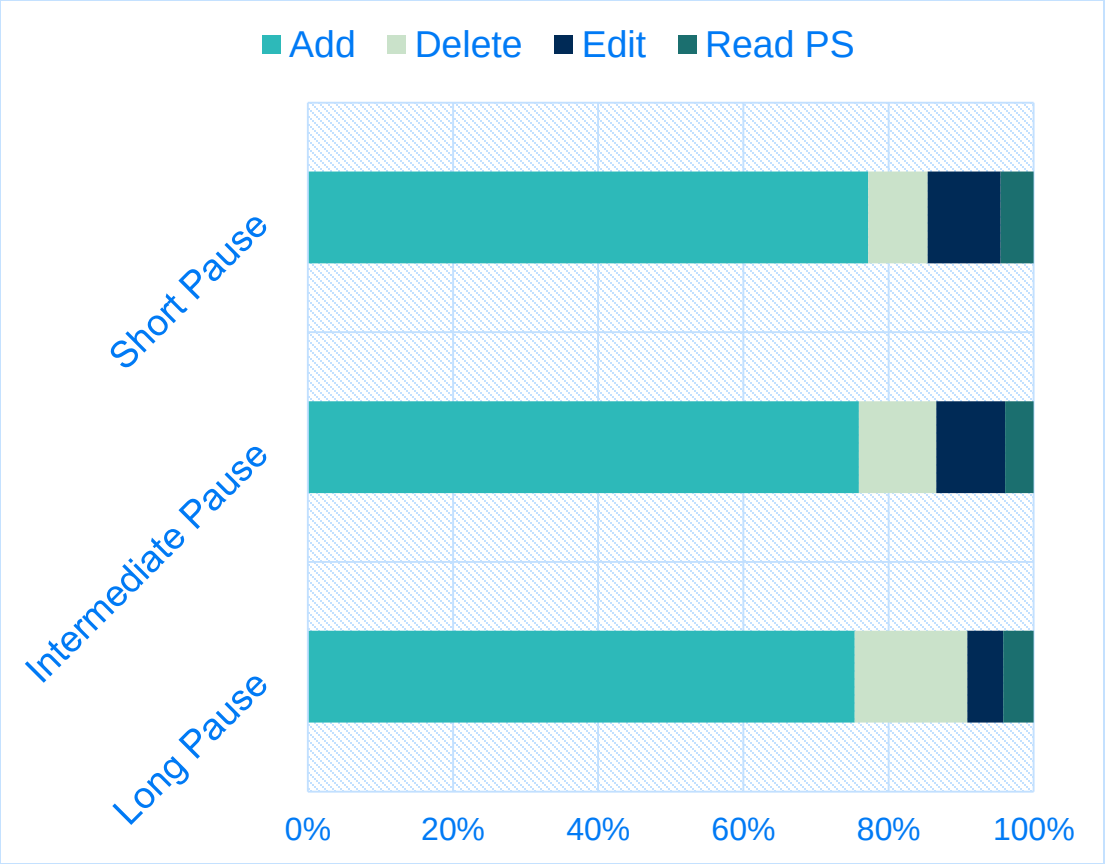
Results: Activity After Pauses

- Add activity most likely after any pause
- Delete slightly more likely for long pauses
- Edit more likely for short and intermediate pauses



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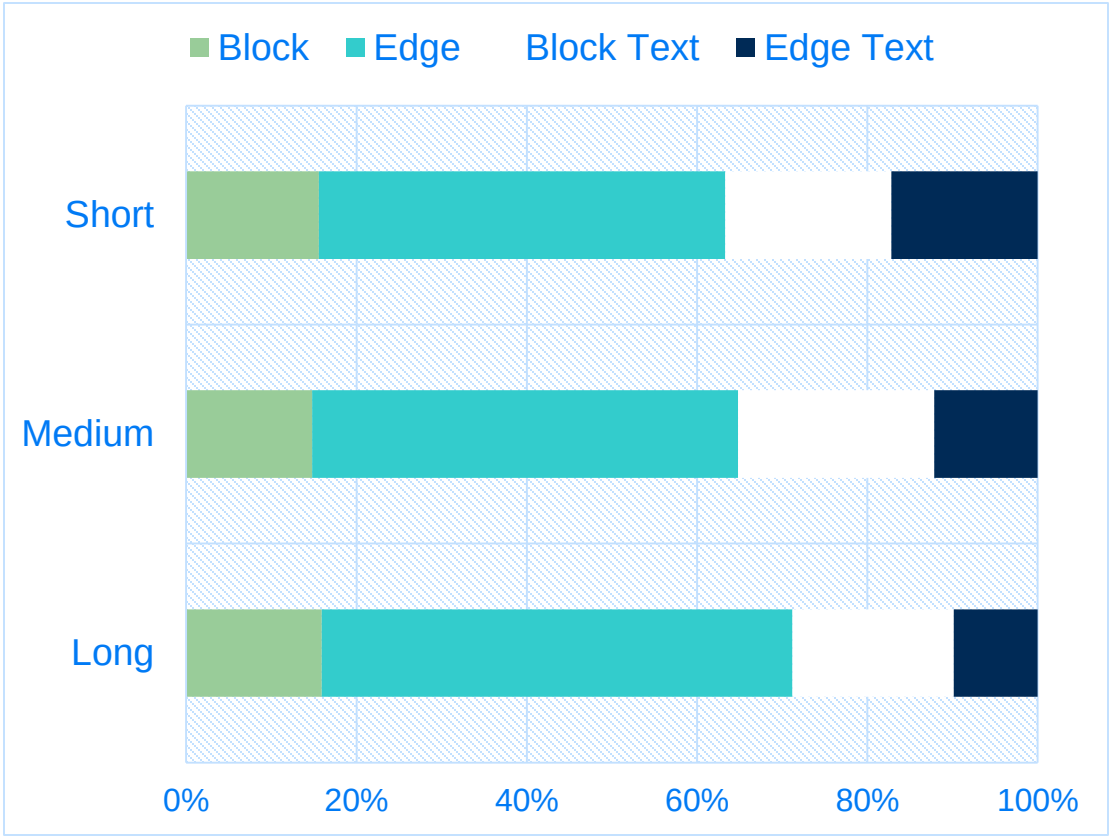
Results: Elements After Pauses

- Edge most likely after any pause
- Block and block text similar after all pauses
- Edge text more likely after shorter pauses



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Conclusions

- Pause length and frequency
  - Graduate students spend more time more frequently in pauses
  - Most students spend between 30% to 60% of time in pauses

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QUESTIONS?

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BACKUP SLIDES

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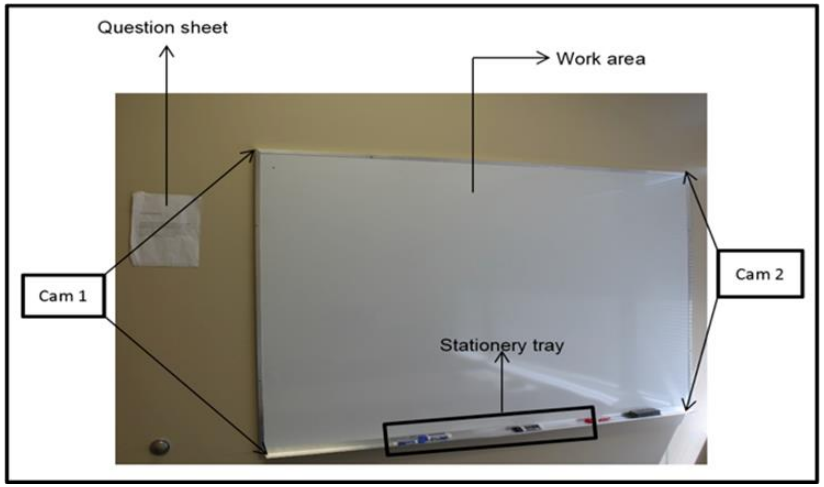
Motivation: Previous Work (Protocol)

- Initial Protocol Study
  - 8 ME graduate students
  - Video recording of modeling activity
  - Video coding and Analysis
    - Add, delete, edit, and pauses



- Observations from initial protocol studies
  - Modeling patterns are likely to exist in designer behavior
    - Model chaining
      - Forward Chaining
      - Backward Chaining
      - Nucleation
    - Pause patterns
      - Pause Length and Frequency
    - Rate of model growth

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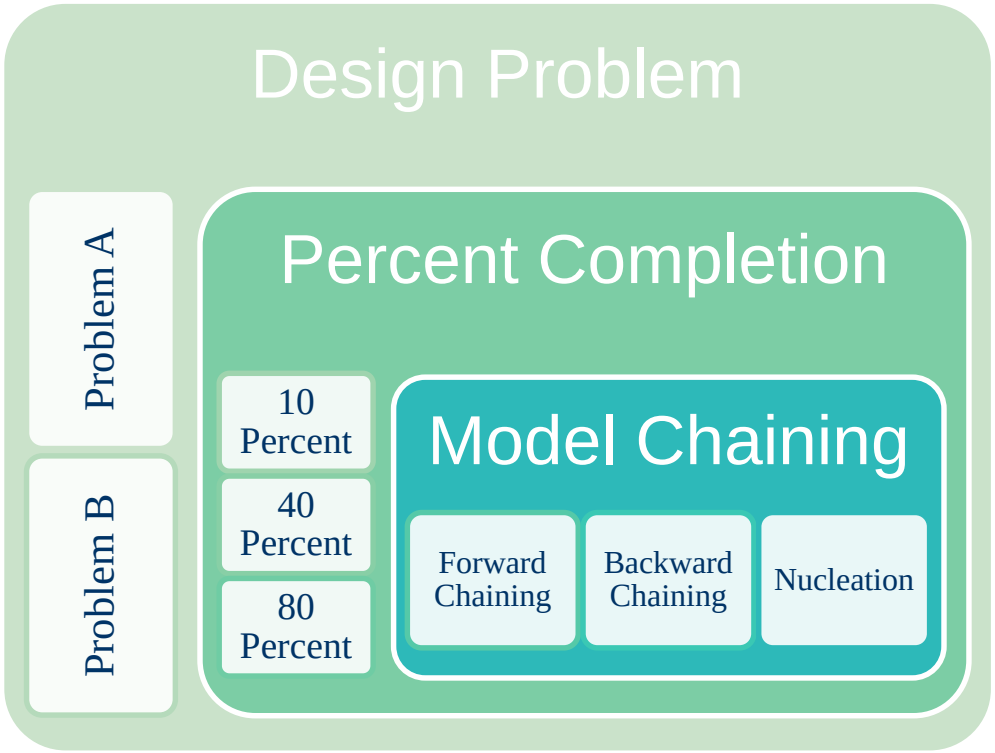
Motivation: Previous Work (User Study)

- Two design problems
  - Automatic folding and ironing machine
  - Automatic recycling sorter
- 86 participants
- 2 models per participant
- Conducted as class activity
  - 1st semester ME Senior Design
- Mixed factorial experiment
  - Between subject replication
  - Within subject replication
- Experimental packet
  - Both design problems
  - Two different chaining method
  - Two different completion levels



- Information collected
  - Number of functions added
  - Number of flows added
  - Model Evaluation

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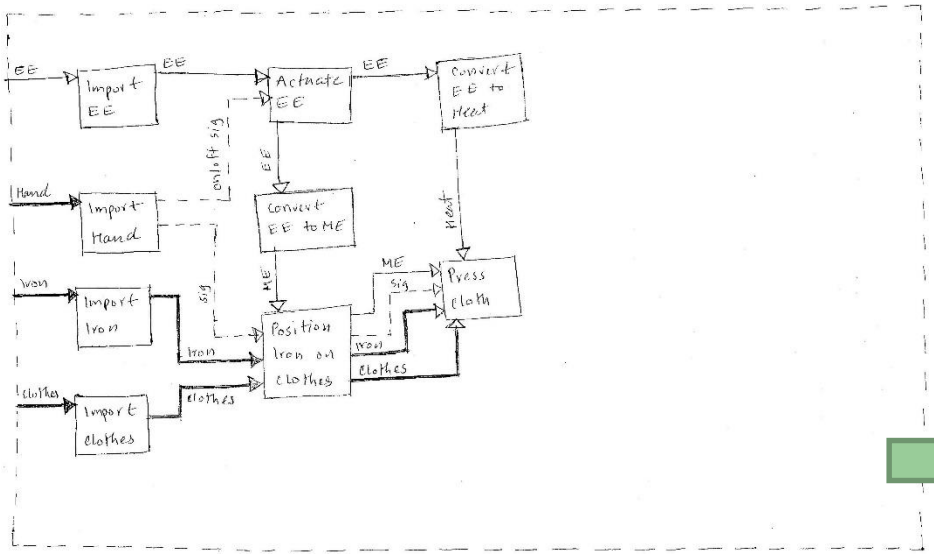
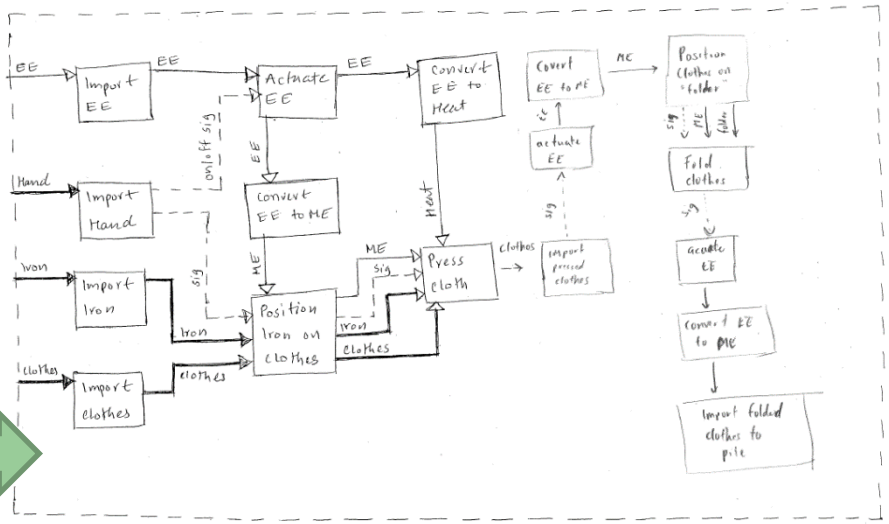
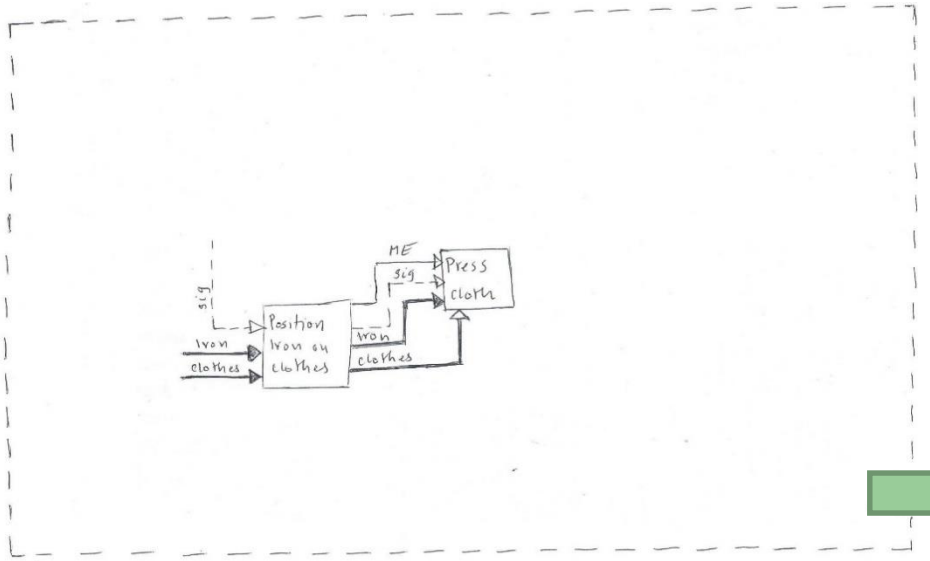
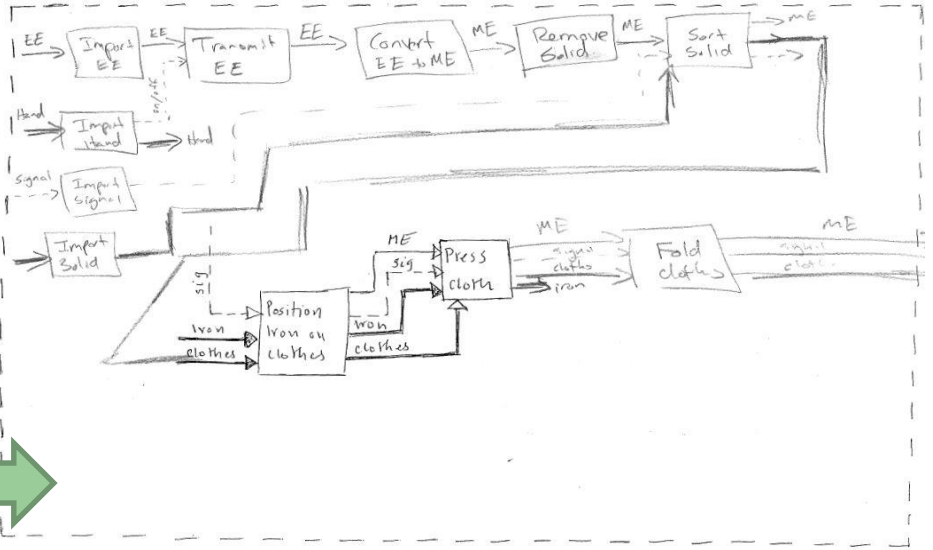
Partially Completed Function Structures









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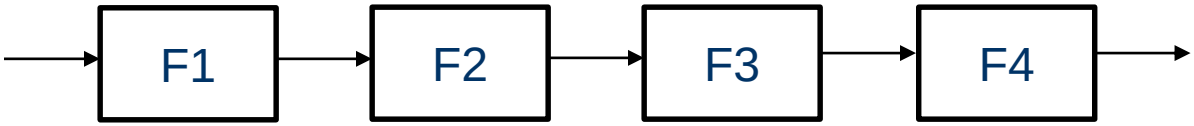
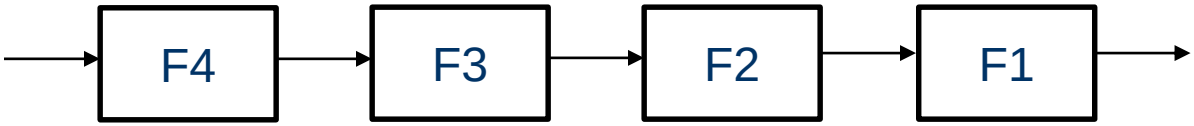
Chaining Methods

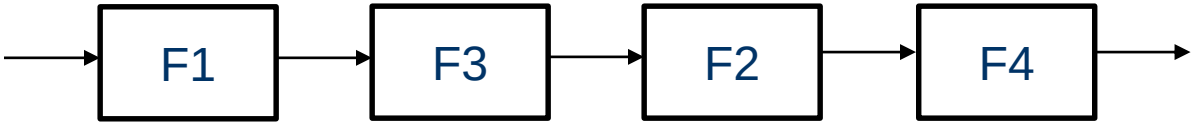
- Forward chaining



- Backward chaining



- Nucleation chaining



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Design Problems

Automatic Clothes Ironing

Design an automatic clothes-ironing machine for use in hotels. The purpose of the device is to press wrinkled clothes as obtained from clothes dryers and fold them suitably for the garment type. You are free to choose the degree of automation. At this stage of the project, there is no restriction on the types and quantity of resources consumed or emitted. However, an estimated 5 minutes per garment is desirable.

Automatic Recycling Sorter

Design an automatic recycling machine for household use. The device should sort plastic bottles, glass containers, aluminum cans, and tin cans. The sorted materials should be compressed and stored in separate containers. The amount of resources consumed by the device and the amount of space occupied are not limited. However, an estimated 15 seconds of recycling time per item is desirable.

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Problem Similarity

- Two design problems selected to be similar
  - Similar word count (70 and 61)
  - Similar number of functions (3 each)
- Similar participant response
  - No significant difference
    - Functions and Flows

	Variable 1	Variable 2
Mean	0.835748	0.713711
Variance	0.829389	0.406609
Observations	86	86
Hypothesized Mean Difference	0	
df	152	
t Stat	1.017962	
P(T<=t) one-tail	0.155157	
t Critical one-tail	1.65494	
P(T<=t) two-tail	0.310314	
t Critical two-tail	1.975694	

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Protocol Study Results

- A protocol study was conducted at Clemson University
  - 8 participants (one model each)
  - Record and observe modeling behavior
  - Code modeler activity and analyze for patterns
- Observations from the study
  - Functions are always labeled
  - Largest addition or deletion was 9 elements
  - Forward chaining was predominantly used for modeling
    - 84% forward chaining
    - 14% Nucleation
    - 2% backward chaining
- Research gaps
  - Small participant pool
  - Only one design problem used
  - Only one model drawn per participant

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Interdependence in Progressive Ideation

- Interdependence occurs in groups
  - Concept from organizational psychology
  - Stems from differences in perception of concepts
- Pooled interdependence
  - Individual activity
  - End product is an accumulation
- Sequential interdependence
  - Individuals modify partially completed work
  - Work is completed in a sequence
  - Examples: C-Sketch, Method 6-3-5
- Reciprocal Interdependence
  - Individuals exchange work within the group
  - Work is completed after iterations
  - Example: Gallery Sketching

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Model Evaluation Rubric

- Model contains a black box?
- Black box contains input and output flows?
- Are the input and output flows in the black box appropriate?
- Does the black box represent flow conservation?
- Do inputs from the black box match functional model inputs?
- Do outputs from the black box match functional model outputs?
- Does the functional transformation described by the black box represent a plausible overall system functionality?
- Does the black box function–flow pair take the general form a verb/noun pair?
- Do the function–flow pairs in the functional model overall represent a plausible view of the product?
- Do the function–flow pairs in the functional model take the general form of a verb/noun pair?
- Is the functional model free of nonsensical functions?
- Is the functional model free of nonsensical flows?
- Is the model free of instances where the system acts on the system?
- Is flow directionality consistent with the transformation in the functions?
- Are flows conserved across function transformations?
- Are flow paths appropriate for product representation?
- Does the functional model represent flow conservation?
- Are the proper energy, material, and signal flow arrow conventions followed?

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