A User Study on Information that can be extracted from Engineering Design Representations

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Outline

- Motivation for conducting experiment
- Hypothesis
- Experiment Procedure
- Experiment Results
- Conclusions
- Future Work

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Motivation for Experiment

- Research has been done on engineering representations
  - examples: comparing text vs. sketch, interface of CAD software, prototype taxonomy
- We know that representations are useful for idea generation, problem solving, and communication…but which do you use and when?
- Conduct an experiment that examines the type of information designers can extract from engineering representations!
  - Type: Functional, geometric, manufacturing

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Hypothesis

- Increased fidelity will increase the amount information extracted
- Increased fidelity will increase the correctness of the information extracted
- Increased fidelity results in higher confidence of the designer when examining the representation

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Experiment Overview

DIRECTIONS
Mark the answer that most closely matches whether you believe the design meets that specific requirement based on this representation.

Requirement	Does not meet	May not meet	Can't tell	Possibly meets	Does meet
Have the ability to vary a normal (straight down) load up to 500kg	○	○	○	○	○
Must not exceed floor space of 10mx10m	○	○	○	○	○
Measure applied load	○	○	○	○	○
Use recyclable materials	○	○	○	○	○
Use readily available materials	○	○	○	○	○
Apply a load vertically within 5° range	○	○	○	○	○
Be able to lift by 4 people	○	○	○	○	○

Sample Requirement List Survey

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Experiment Procedure

- Each student examined 2 of the 8 representations

The students had:

- 2 minutes to read problem description and ask proctor questions concerning clarification of the directions
- 8 minutes to examine the representation and fill the requirement sheet

Problem Description

Mini-go-round
When designing a lunar capable wheel, the lunar soil, regolith, is capable of generating a significant amount of wear. The regolith is both fine grained and highly abrasive. Thus it is capable of invading virtually any mechanical interface and, overtime, causing damage which could lead to failure. Virtually any material and mechanism will be affected by this wear, but components which use softer materials, feature closed overlapping interfaces, and are in direct contact with the regolith will be at higher risk. These factors identify the tread of the wheel as the component with the highest risk of succumbing to wear failure. Thus it is necessary to choose tread materials carefully and with full consideration of the lunar wear environment. **Develop a test apparatus to evaluate the behavior of wheels on varying terrain.**

Directions

For each requirement, mark the answer that most closely matches whether you believe the design meets that specific requirement based on this representation.

Does not meet: The design definitely does not meet the requirement – *high confidence*
May not meet: Does not appear that the design meets the requirement – *low confidence*
Can't tell: Cannot tell if the design meets the requirement
Possibly meets: Appears that the design meets the requirement – *low confidence*
Does meet: The design definitely does meet the requirement – *high confidence*

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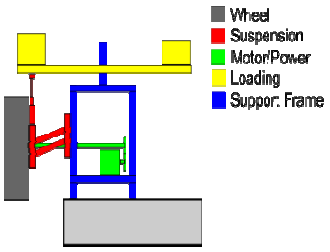
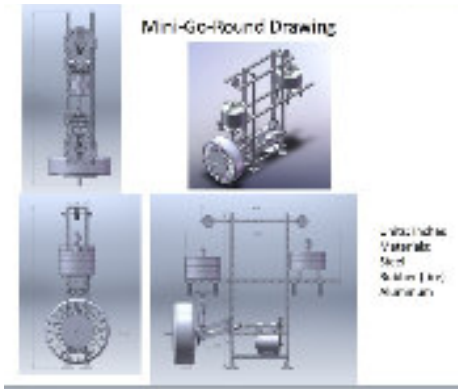
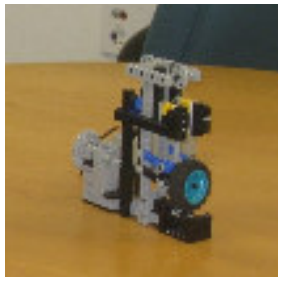
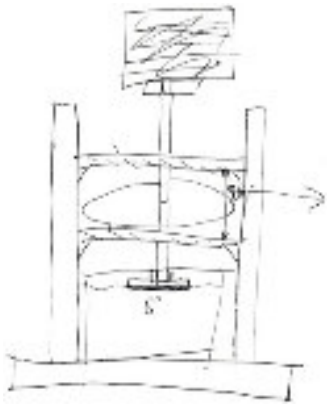
Mini-go-round

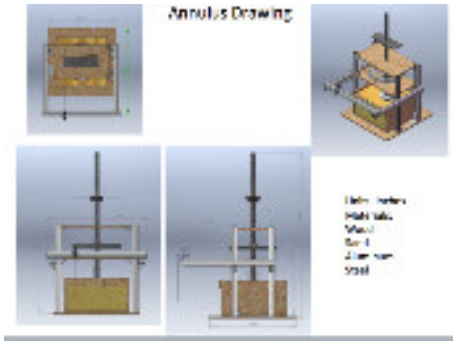






Annulus





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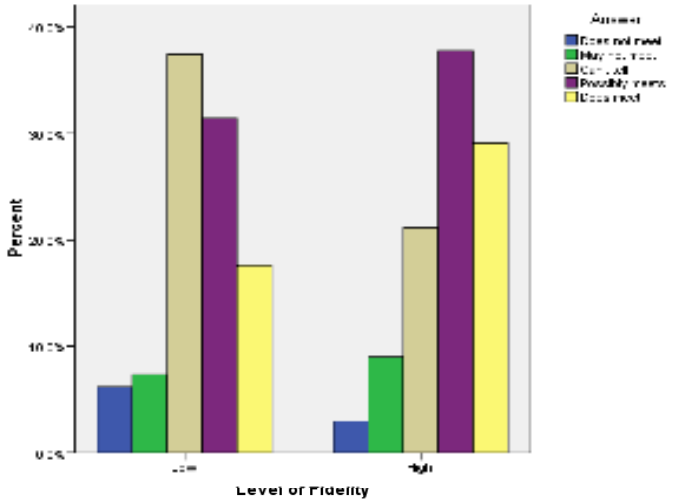
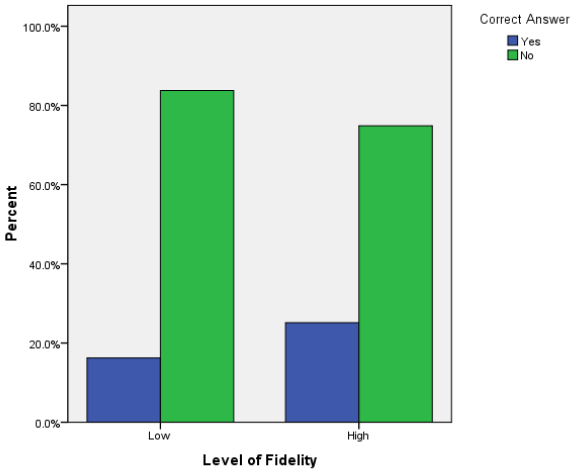
Experiment Results - Fidelity

- Low: Sketches and Low Fidelity Prototypes
- High: Drawing Packages and High Fidelity Prototypes
- More confident and correct for high fidelity representations
- Decrease in Confidence for *Does not meet* responses
- Significant difference in everything except correct answers for functional requirements



Comparison	% "Confidence" Difference from low to high	Significant Difference (Answer)	% of Correct Answers Low/high	Significant Difference (Correct answer)
Level of Fidelity	15.4	Yes (.000)	16.2/26.5	Yes (.000)
Function	10.5	Yes (.000)	16.8/20.7	No (.154)
Geometric	18.4	Yes (.000)	20.9/37.8	Yes (.000)
Manufacturing	19.1	Yes (.000)	13.2/23.5	Yes (.000)



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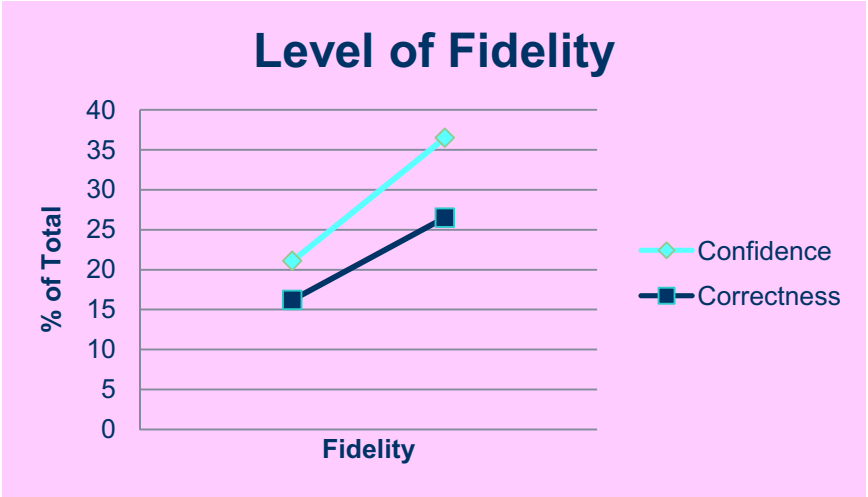
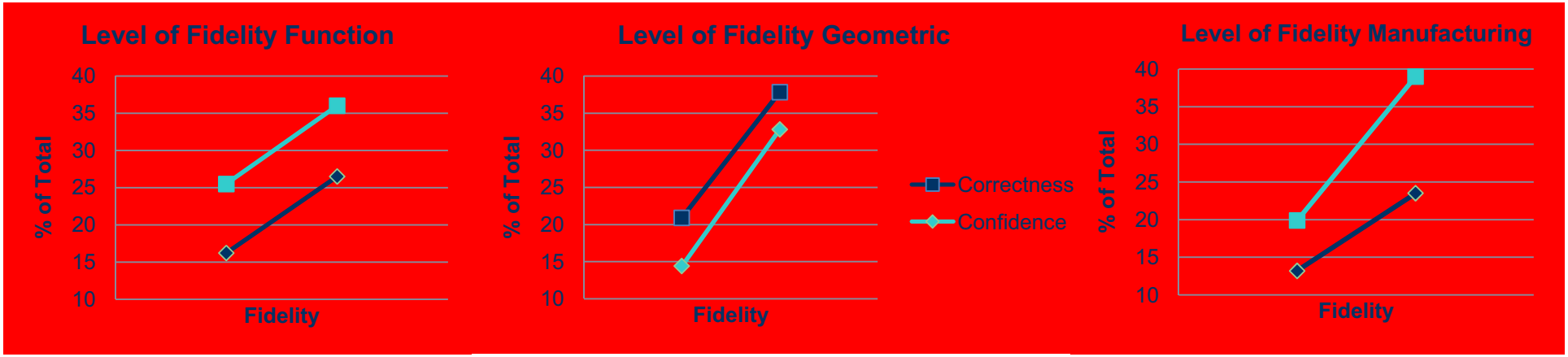
Experiment Results - Fidelity

- Overall confidence increases faster than correctness
- Due to manufacturing requirement type





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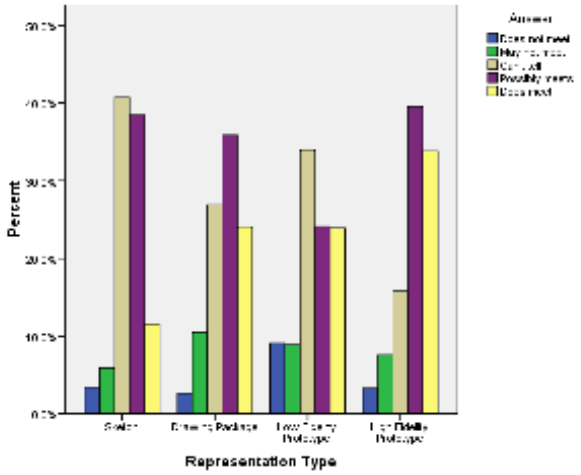
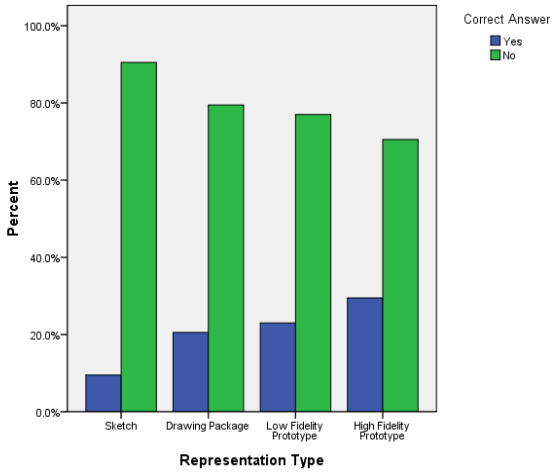
Experiment Results – Type of Representation

- Lowest confidence in sketch and highest in high fidelity prototype
- More confident for low fidelity prototype than drawing package
- But almost equal correctness in drawing package and low fidelity prototype
- More likely to state *Does not meet* a requirement in low fidelity prototypes

Comparison	% "Confidence" Difference between first and second	Significant Difference (Answer)	% of Correct Answers First/second	Significant Difference (Correct answer)
Representation Type	na	Yes (.000)	na	Yes (.000)
Sketch/Drawing Package	13.7	Yes (.000)	9.5/20.5	Yes (.000)
Sketch/Low Fidelity Prototype	8.3	Yes (.000)	9.5/23.0	Yes (.000)
Sketch/High Fidelity Prototype	25.1	Yes (.000)	9.5/29.5	Yes (.000)
Low Fidelity Prototype/ Drawing Package	5.4	Yes (.000)	20.5/23.5	No (.356)
Drawing Package/High Fidelity Prototype	11.4	Yes (.000)	20.5/29.5	Yes (.002)
Low Fidelity Prototype/High Fidelity Prototype	16.8	Yes (.000)	23.5/29.5	Yes (.021)





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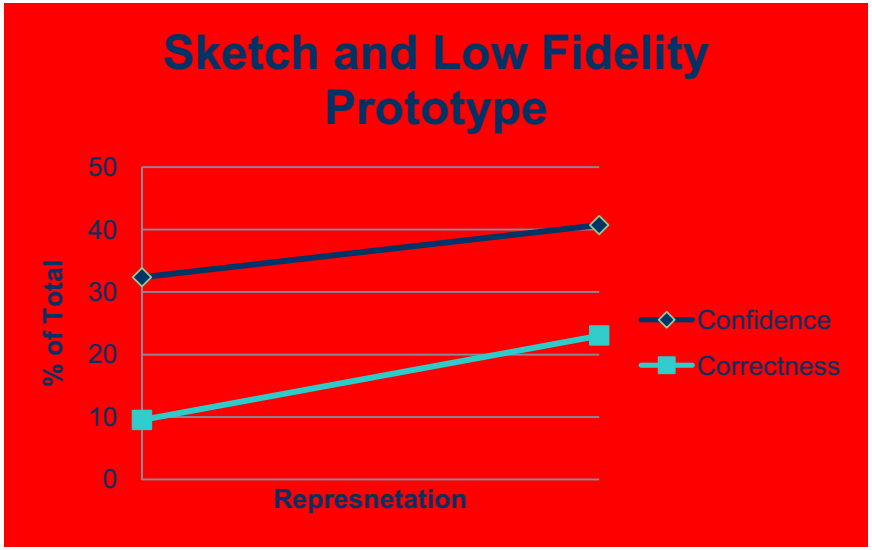
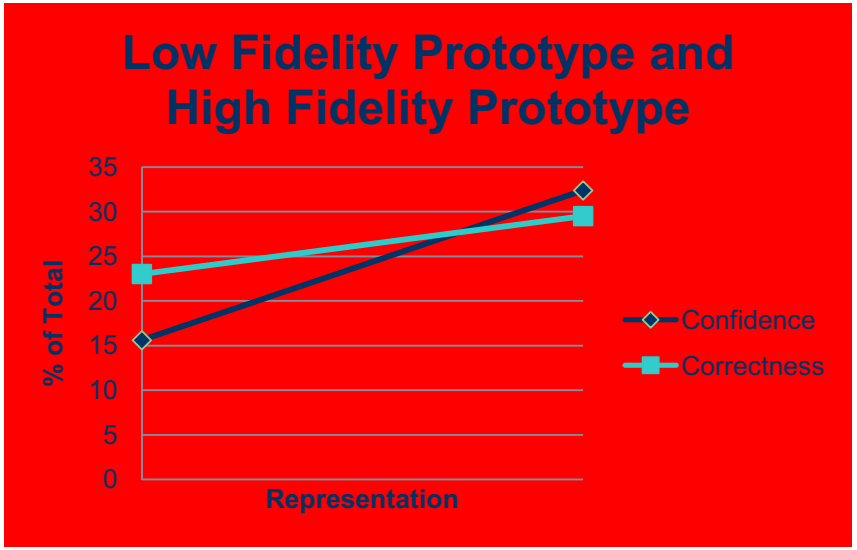
Experiment Results – Type of Representation

From	To	Rate of Change Confidence/Correctness
Sketch	Drawing Package	1.2 Confidence
Sketch	Low Fidelity Prototype	0.6 Correctness
Sketch	High Fidelity Prototype	1.3 Confidence
Low Fidelity Prototype	Drawing Package	2.1 Confidence
Drawing Package	High Fidelity Prototype	1.3 Confidence
Low Fidelity Prototype	High Fidelity Prototype	2.6 Confidence





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Conclusions

Fidelity

- Designers are more confident and correct when using higher fidelity representations
- When using low fidelity representations, designers should look at what the design can meet rather than what it cannot meet

Representations Types

- High fidelity prototypes are preferable for determining whether a design meets specific functional requirements.
- Quick sketches or prototypes can be helpful in determining whether a design meets or has the possibility to meet geometric design requirements.

Designers should be cautious when switching between one representation to another because confidence typically increases faster than correctness.

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…still gotta do…

- Compare order
- Compare between classes
- Compare between designs
- Finish comparing correctness between representation types
- Finish comparing within representations types (*Annulus sketch* to *Mini-go-round sketch*)
- Group into confident and not
- Combine confident groups to analyze correctness further

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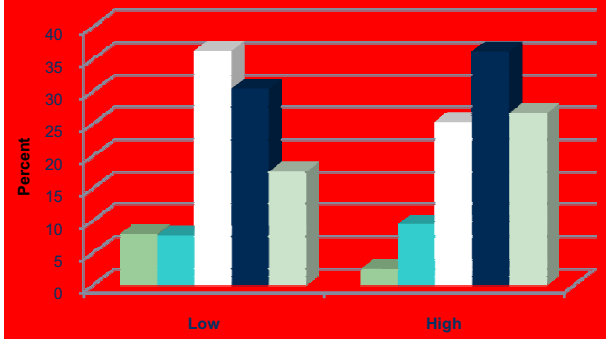
Handout Matrix

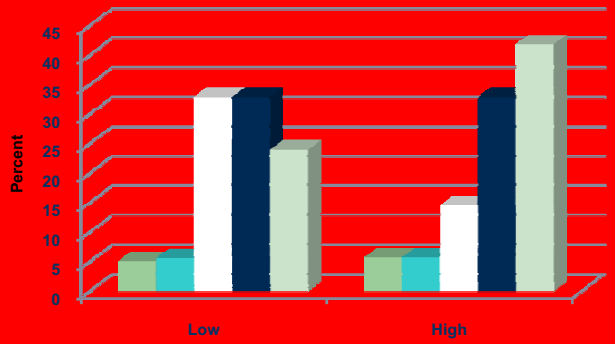
Student	Sk-M	Sk-A	SM-M	SM-A	L-M	L-A	H-M	H-A
1	1					2		
2	1							2
3	2					1		
4	2							1
5		1			2			
6		1					2	
7		2			1			
8		2					1	
9			1			2		
10			1					2
11			2			1		
12			2					1
13				1	2			
14				1			2	
15				2	1			
16				2			1	
17	1							2
18		1			2			
19			1			2		
20				1			2	

Fidelity – Requirement Type

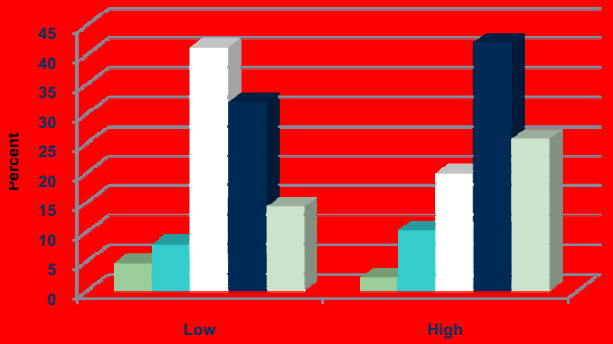
Function

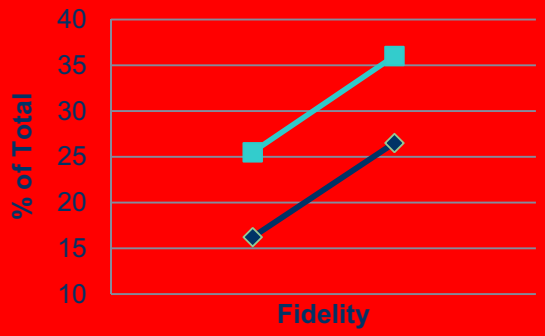


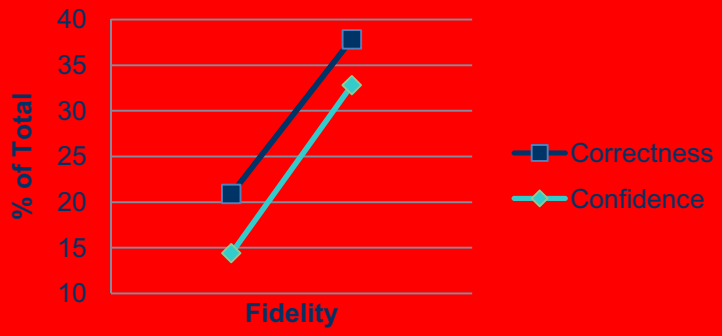
Geometric

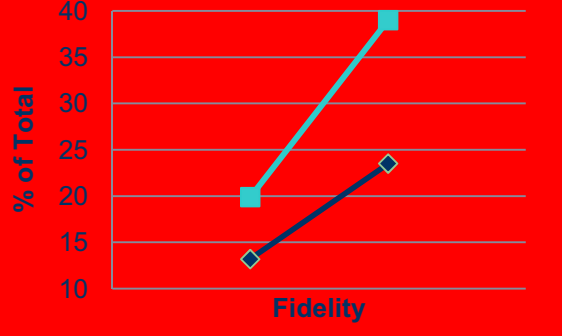


Manufacturing



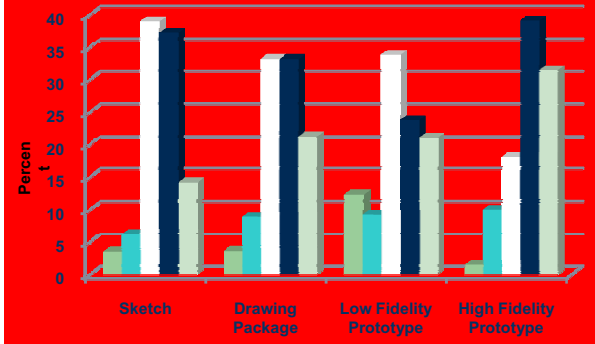




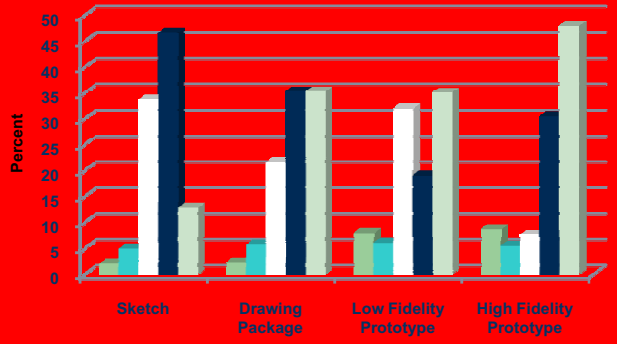


Representation Type – Requirement Type

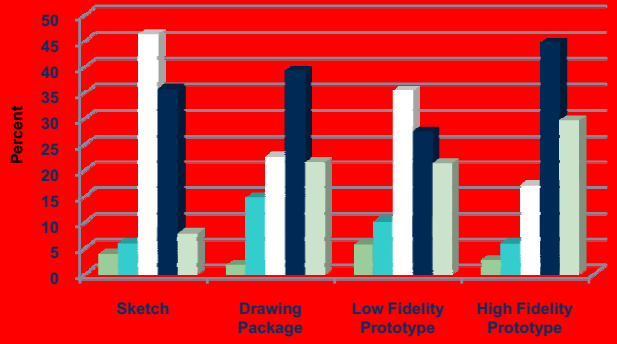
Function



Geometric



Manufacturing



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