DETC2013-12651

Digital Representation of Physical Artifacts: The Effect of Low Cost, High Accuracy 3D Scanning Technologies on Engineering Education, Student Learning and Design Evaluation

Tuesday, August 6th, 2013

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- Research Objective
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- Data Acquisition
- Quantifying Form Similarity

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- Experiment Setup – 3D Scanner
- Survey Results
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Introduction

Research Motivation

- Shift from physical to digital space

- Educators prefer hands-on activities to convey concepts easily to students*.
- Increasing use of technology creates lack in hands-on activities to supplement digital student learning.
- With advancements in digital interactive technology, with products such as *Microsoft's Kinect* and *Nintendo Wii*, the boundaries of hands-on interaction are being pushed into the digital space.

** Gorman et al.*

- Experiments conducted by Stanford University with their bicycle disassembly course have shown that students learn better when multimedia tools are employed as part of the existing teaching methodology*.
- Digital tools such as the **3D scanner**, **livescribe digital pen** and the **voice to text** feature have accelerated and improved the process of information extraction through simple hands-on activities.

** Regan and Sheppard*

Research Motivation – contd.

- Automated student assessment techniques

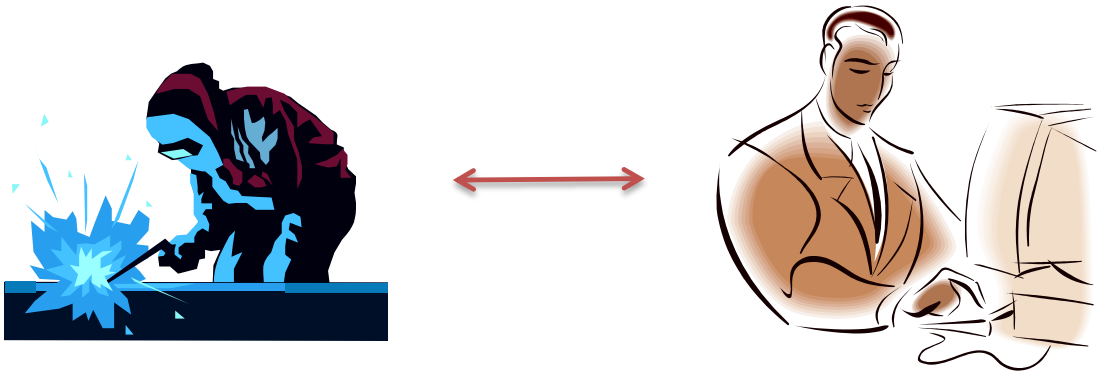
- Variations across digital model assessments given by graders (teaching assistants). Increase in student designs, increases the variations in grades and the number of graders.
- Automated grading solutions have focused on textual and choice based response data to a large extent*. Techniques to quantify qualitative design data has not been explored.

** Zoeckler* and *Valenti et al.*

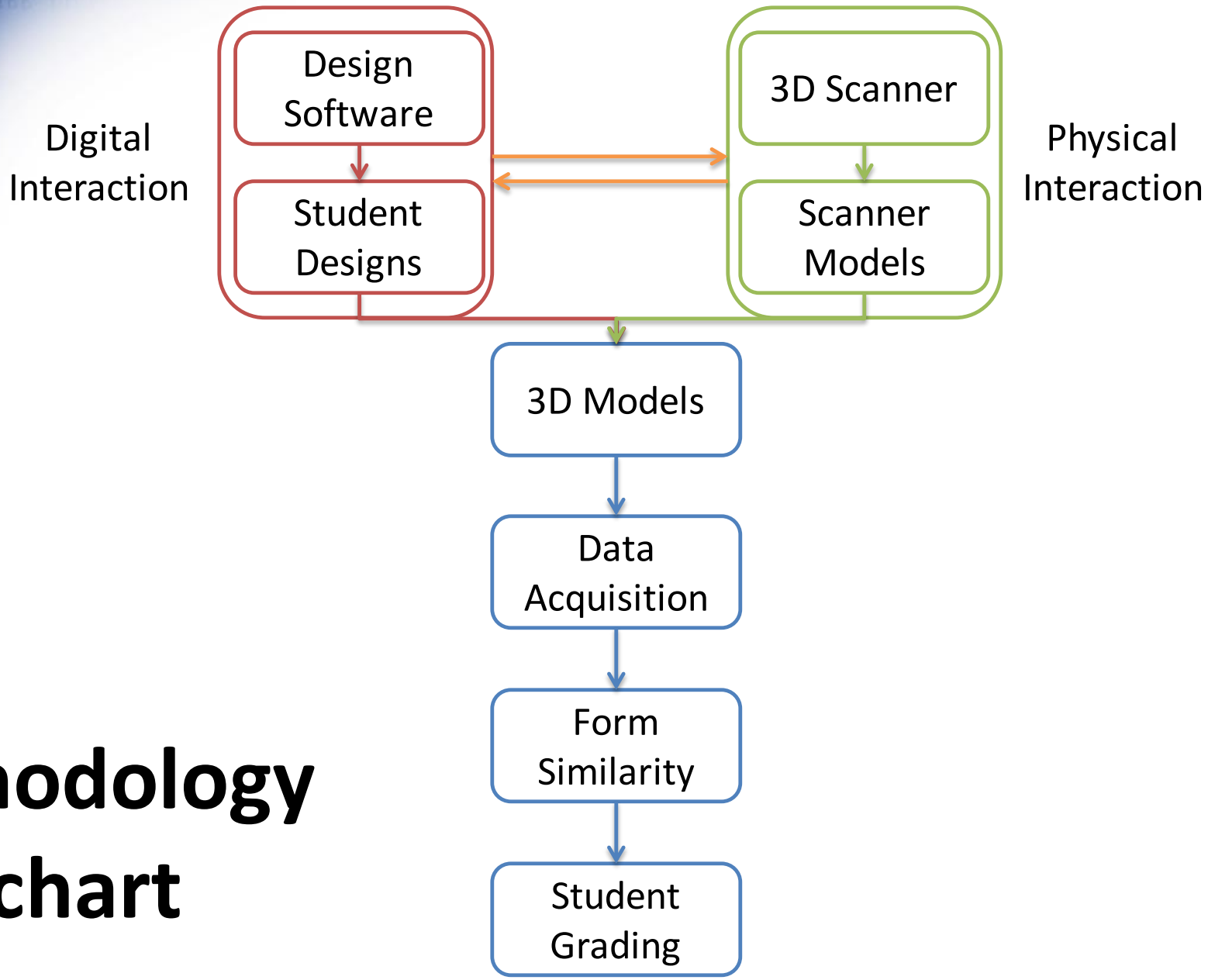
Methodology

Research Objective

- To help bridge the gap between digital design education and hands-on experiences in design classrooms.
- Assess variations in grading across student design activities.



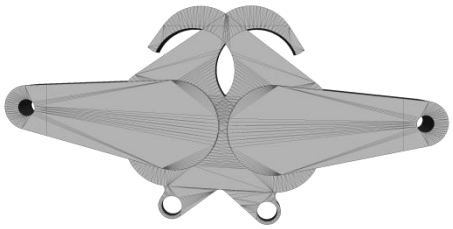
Methodology Flowchart



Proposed Methodology

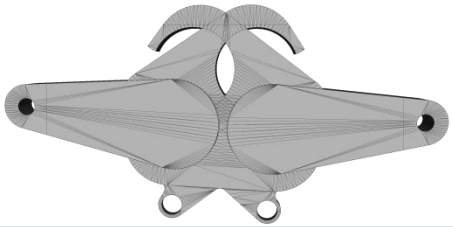
- Introduce 3D scanning as a technique to supplement digital model creation through hands-on interaction with live artifacts.
- Use degree of form similarity as a measure to evaluate student designs benchmarked against a standard model.

- Sample 3D Scanner.



Vs.

- Sample object to object comparison.



Data Acquisition

3D Models - Stereo lithography files

Design 1

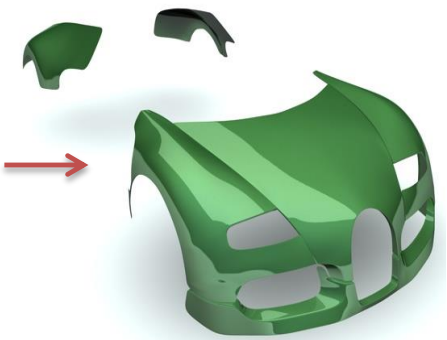
Design 2

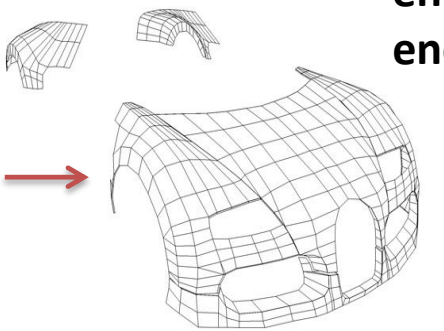
Design 3

Wire-mesh

facet normal n_i n_j n_k
outer loop
vertex $v1_x$ $v1_y$ $v1_z$
vertex $v2_x$ $v2_y$ $v2_z$
vertex $v3_x$ $v3_y$ $v3_z$
endloop
endfacet

facet normal n_i n_j n_k
outer loop
vertex $v1_x$ $v1_y$ $v1_z$
vertex $v2_x$ $v2_y$ $v2_z$
vertex $v3_x$ $v3_y$ $v3_z$
endloop
endfacet



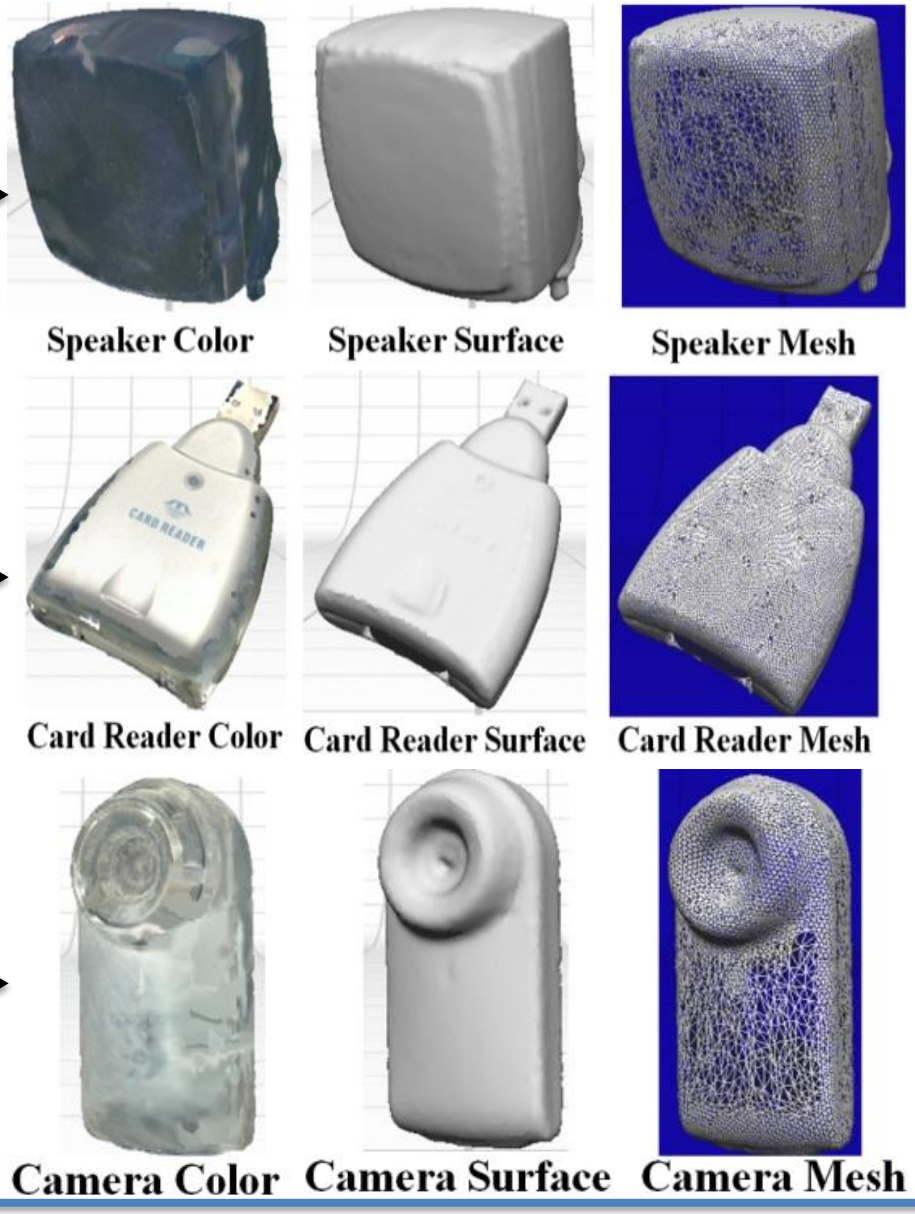


Data Acquisition – contd.

- 3D scanners are digital image and depth capturing devices which help create digital 3D models of objects.
- They consist of a combination of photographic lenses to capture images and lasers to capture point by point depth values across the surface of the artifact.

3D Scanner - Sample

- 3D Scanner in a classroom setup along with generated 3D models of objects.

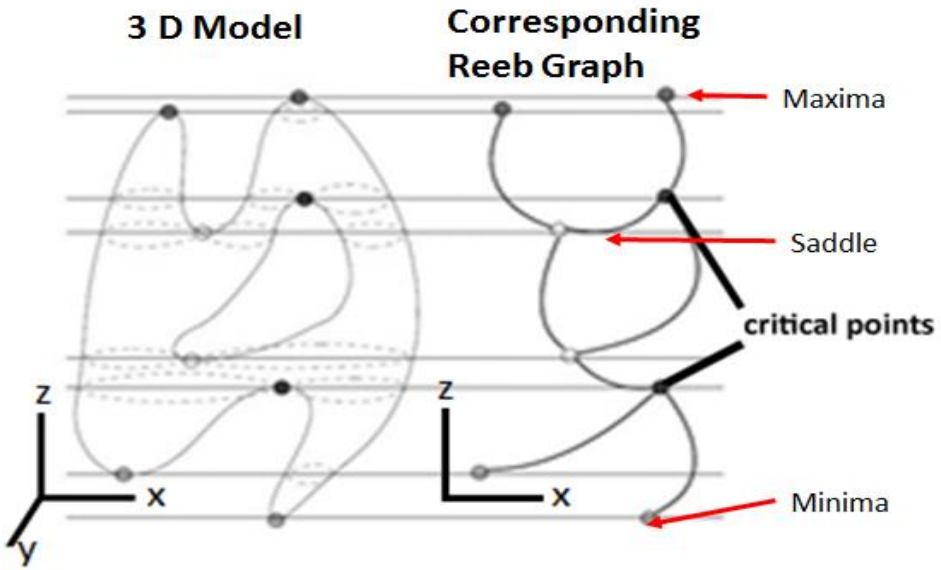


Form Similarity

- Generated student 3D models (STL files) are compared with the model created by the scanner using the form similarity metric using the evaluation of reeb graphs as generated by *Doraiswamy et al.*
- Form similarity by definition is the evaluation of degree of alikeness in form (pure geometric) between two artifacts.
- The result gives a relative value of the deviation from standard when comparing various models to a benchmarked model.

Reeb Graphs

- Reeb graph is a form visualization technique based on Morse theory which evaluates geometry of objects based upon the surface topology through the determination of iso-surface parameters along increasing level set values (along Z-axis).



- Similarities in Reeb graphs represent similarities in models through the analysis of identical critical points in the Reeb graph.

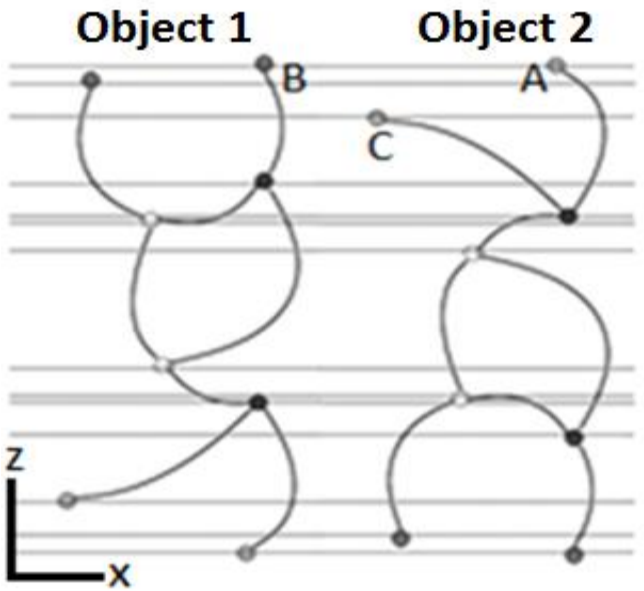
**Doraiswamy et al.*

Reeb Graphs – contd.

- Reeb graphs can be compared for similarities through a comparison of the level set data for each reeb graph.
- The degree of similarity is a direct correlation to the level of similarity between the two 3D models.

Level set data		
Saddle	Maxima	Minima
1	0	0
2	0	2
3	6	5
.	.	.
1543	1554	1023

- Sample of generated data.
- Reeb graph comparison – visualization.



Quantitative Assessment

- Student designs created are compared for similarities in form using the reeb graph technique.
- Comparisons are done between student designs and a benchmark design either generated from a 3D scanner or present in the product database.
- Student grades are a direct representation of the degree of similarity between the comparisons (e.g. similarity value of 0.86 correlates to a grade of 86/100).

Case Study

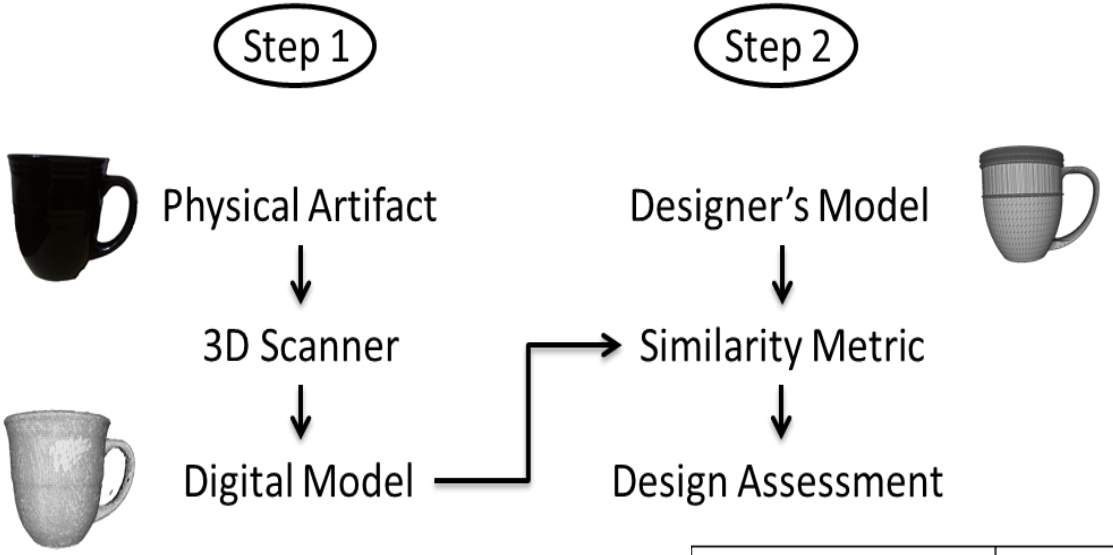
Data Set

- Models generated by Students on *Solidworks*.

Object

- Model generated by the *Nextengine®* 3D Scanner.

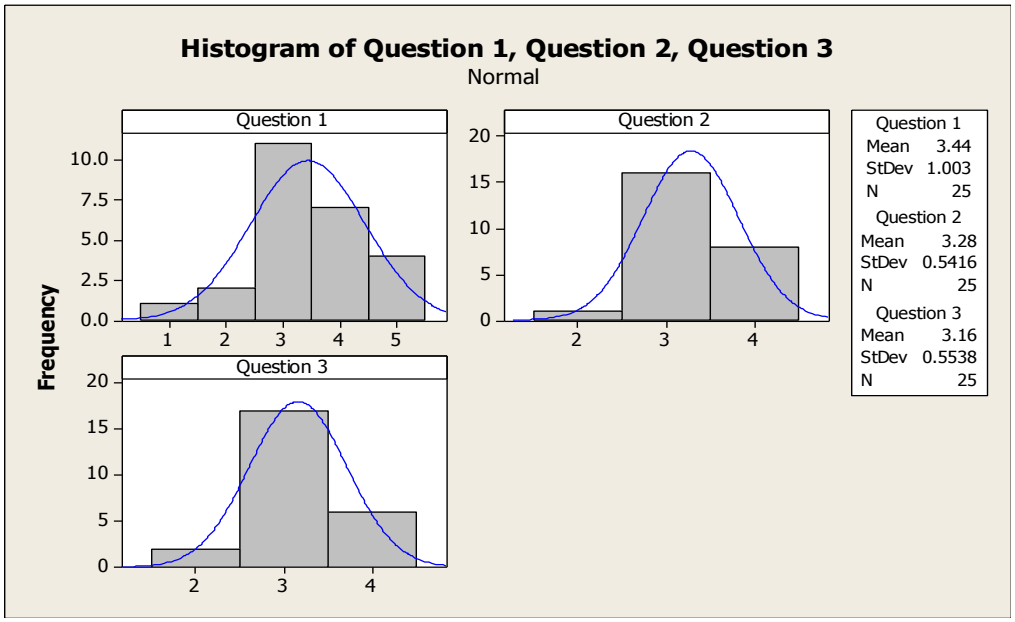
Design Assessment



3D Scanner Model	Student Models
	
	
	
	

- 25 Students created the model of the coffee mug during a lab class of 2 hours duration.
- Each student was given identical mugs and were asked to recreate the model using the standard *Solidworks* design package.

- Additional Survey Questions- 3D Scanner



On a scale of 5 (5 being the easiest):

Q1: How much easier was it to regenerate a solid part using the scanner as opposed to designing it on the software?

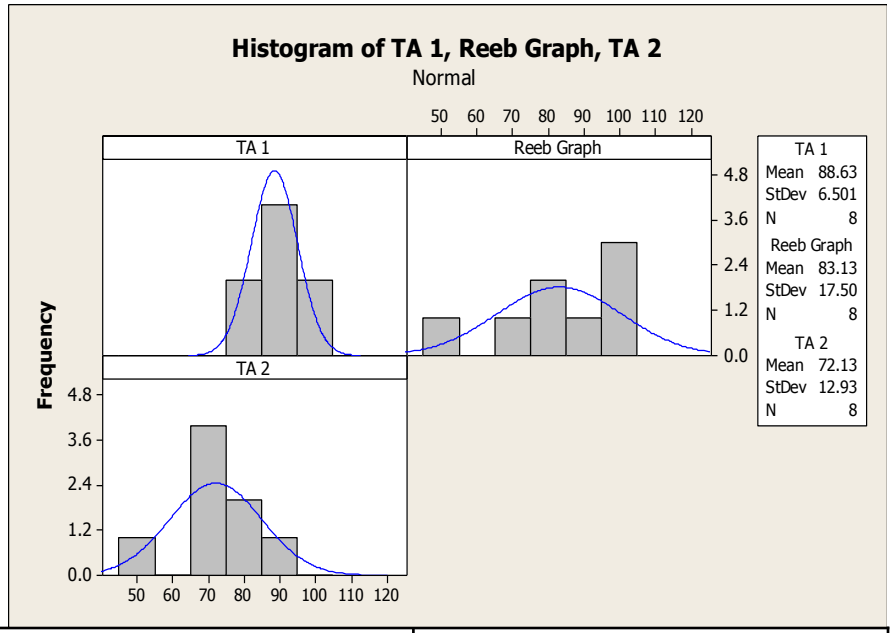
Q2: How easy was it to learn the working of the scanner?

Q3: How easy was it to navigate through the software that is associated with the scanner for scanning?

Results for student assessment

Student	Student Model	TA 1 Score	TA 2 Score	Scores from reeb graph
1		87	69	91
2		78	47	78
3		95	90	100
4		92	73	49
5		95	84	76
6		90	68	74
7		80	68	98
8		92	78	99

- Results from Student design assessment



Statistic	TA 1	TA 2
Mean	88.63	72.13
Std. Deviation	6.5	12.93
One sample t at 95% CI	(83.19,94.06)	(61.31,82.94)
Estimate of difference	16.5	
95% CI for difference	(5.0968, 27.9032)	
T – value	3.22	
P – value	0.009	

Conclusion

- The conducted research aims to aid in bridging the gap between digital and hands-on activities in design classroom by introducing 3D scanners as a tool to create digital models of objects.
- Variations in assessments of student generated models across graders is eliminated through the automated evaluation of models by similarity comparison to a benchmarked model.

Questions
Comments