

The Boston Museum of Science BEST Project

Interim Evaluation Report

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Executive Summary

The following report presents the findings from the evaluation research conducted by Davis Square Research Associates (DSRA) on the Boston Museum of Science Bridging Engineering, Science and Technology (BEST) project, funded by the National Science Foundation, and designed to strengthen the teaching and learning of engineering content in elementary school teacher preparation programs. The current report summarizes participating college undergraduate survey data from six participating colleges.

Key findings include:

- Participant judgments on statements related to engineering changed to resemble more closely the judgments on the same statements as made by engineering experts
- Student results seemed to vary from college to college
- Preliminary principal components analysis indicates that the instrument may require further refinement.

Sample & Method

The sample for the report includes students (N=183) from the classes of participating faculty (N=11) in the BEST project, with the student participants being undergraduate students from six Massachusetts colleges.

The following two tables summarize the number of participants by college at both the pre-test and post-test moments.

Table 1: Pre-Test Students by College

		N: Pre-Test	Total
College Number	Fitchburg	86	86
	Massasoit	19	19
	MCLA	3	3
	MCC	24	24
	Salem State	40	40
	Westfield	11	11
Total		183	183

Table 2: Post-Test Students by College

		N: Post-Test	Total
College Number	Fitchburg	45	45
	Massasoit	19	19
	MCLA	2	2
	MCC	1	1
	Salem State	11	11
	Westfield	11	11
Total		89	89

The data from the survey items related to the participants' skills at judging the correctness of a series of 31 statements about engineering. These statements (presented below in the item-by-item presentation) have already been judged by a group of 94 experts in engineering and engineering education from across the US. The point of the instrument is to see whether the judgments expressed by the student participants come to more closely approximate those of the experts

The key questions for the survey were:

- Have the students' responses to ambiguous statements about engineering come closer to those of engineering professionals?
- How valid is the engineering judgments survey?

This section examines first the gains that the students may have made in the responses to the judgments survey, and then DSRA presents the preliminary findings from a validation study of the instrument itself.

The following table summarizes the instances of significant difference from the engineering judgments expressed by the expert group. Note that the MCC is dropped from post-test analysis as no post-hoc tests can be done with fewer than two cases.

Table 3: Pre-Post Changes Summarized

College	Process (N=19)		Context (N=5)		Products (N=7)	
	Pre-	Post-	Pre-	Post-	Pre-	Post-
Fitchburg	17	13	5	5	7	5
Massasoit	13	3	3	2	7	4
MCLA	6	0	2	1	6	1
MCC	10		5		7	
Salem State	13	1	5	1	7	1
Westfield	10	13	3	0	7	1
Total/Total Possible	69/114	30/95	23/30	9/25	41/42	12/35

DSRA found 133 instances of pre-test differences (of 186 possible instances of difference, or 72%), while at the post-test DSRA found 51 (of 155 possible instances, or 33%). In other words the instances of disagreement with the experts were cut roughly in half – a huge improvement. These gains are clearly very strong and provide a strong indication of project effectiveness.

Looking at the percentage gains by domain and college, DSRA found the following percentage gains:

Table 4: Percentage Gains by College & Domain

College	% Process Gain	% Context Gain	% Products Gain	% Overall Gain
Fitchburg	24%	0%	29%	21%
Massasoit	77%	33%	43%	61%
MCLA	100%	50%	83%	86%
Salem State	92%	80%	86%	88%
Westfield	-.33%	100%	86%	30%

Note that some colleges reported better findings than did others. The reasons for this cannot be ascertained on the basis of the available data, however the variation in the results is quite apparent and surely merits further investigation.

Differences by Domain and Item

The following series of tables present the engineering judgments item by item, with the pre- and post-tests being divided into the three domains of the instrument, namely process, context, and products. The items marked as significant indicate instances in which the student group differed significantly from the expert group. Instances in which the students from one college differed significantly from those of another college are *not* identified.

Table 5: Pre-Test: Process

		N	Mean	Std. Deviation
Process: An engineer should test materials before creating a design that uses those materials.	Expert	94	7.415	2.550
	Fitchburg	86	8.267	1.931
	Massasoit	19	8.158	2.986
	MCLA	3	9.000	1.732
	MCC	24	8.375	2.102
	Salem State	40	8.425	2.049
	Westfield	11	9.455	0.688
Process: Analysis of data helps engineers make informed design decisions.	Expert	94	7.436	2.538
	Fitchburg*	86	8.384	1.667
	Massasoit	19	8.579	2.244
	MCLA	3	10.000	0.000
	MCC	24	8.708	1.853
	Salem State*	40	8.700	1.454
	Westfield*	11	9.364	0.674

Pre-Process con't.		N	Mean	Std. Deviation
Process: Engineering design is an iterative process.	Expert	94	9.553	0.771
	Fitchburg*	86	6.721	1.883
	Massasoit*	17	5.824	2.270
	MCLA	3	8.000	1.000
	MCC*	24	6.417	2.339
	Salem State*	40	7.350	1.942
	Westfield	11	8.091	1.700
Process: Engineering failures are an important source of engineering knowledge.	Expert	92	9.239	1.401
	Fitchburg*	86	8.070	1.987
	Massasoit	19	8.263	2.600
	MCLA	3	7.333	3.055
	MCC	23	7.870	2.564
	Salem State	40	9.175	1.318
	Westfield	11	8.546	1.368
Process: Engineers don't need to know much about math.	Expert	92	9.239	1.417
	Fitchburg*	86	2.128	2.206
	Massasoit*	19	2.579	3.097
	MCLA*	3	1.333	0.577
	MCC*	24	2.583	2.977
	Salem State*	40	1.825	2.099
	Westfield*	11	1.455	0.820
Process: Engineers often cycle through the engineering design process again and again as they work on a single problem.	Expert	93	2.172	2.150
	Fitchburg*	86	7.523	1.845
	Massasoit*	19	8.000	2.517
	MCLA*	3	7.667	2.517
	MCC*	24	7.833	2.057
	Salem State*	40	7.775	2.178
	Westfield*	10	7.900	2.025
Process: Engineers often work in teams.	Expert	93	9.043	1.334
	Fitchburg*	86	7.395	1.930
	Massasoit*	19	7.579	2.854
	MCLA	3	8.667	2.309
	MCC*	24	7.583	2.205
	Salem State	40	8.000	1.961
	Westfield	10	8.200	2.201
Process: Engineers typically work alone.	Expert	94	9.266	1.228
	Fitchburg	86	3.791	2.064
	Massasoit	19	3.632	2.565
	MCLA	3	5.000	4.583
	MCC	24	3.625	2.946
	Salem State	40	3.050	1.934
	Westfield	11	3.000	1.897

Pre-Process con't.		N	Mean	Std. Deviation
Process: Because engineers use science and math, they almost always get the same answer.	Expert	94	2.181	1.311
	Fitchburg*	86	3.826	2.192
	Massasoit*	19	4.000	2.134
	MCLA	3	5.333	2.309
	MCC*	24	3.708	2.312
	Salem State*	40	3.625	2.261
	Westfield	11	4.000	2.145
Process: Engineers use science in their work.	Expert	94	2.404	1.891
	Fitchburg*	86	8.488	1.577
	Massasoit*	19	8.421	2.501
	MCLA*	3	8.000	2.646
	MCC*	24	8.333	2.426
	Salem State*	40	8.600	1.766
	Westfield*	11	9.091	0.944
Process: Feedback is important to the engineering design process.	Expert	94	8.979	1.422
	Fitchburg*	86	8.221	1.482
	Massasoit	19	9.053	1.433
	MCLA	3	9.000	1.000
	MCC	24	8.333	1.880
	Salem State	40	8.650	1.494
	Westfield	11	8.818	1.168
Process: Innovation and creativity are important to the engineering design process.	Expert	93	9.538	0.745
	Fitchburg*	85	8.071	1.624
	Massasoit	19	9.000	1.491
	MCLA	3	7.667	2.517
	MCC*	24	7.958	2.596
	Salem State*	40	8.525	1.569
	Westfield	11	8.546	1.440
Process: More than one design may be acceptable for a given problem.	Expert	94	9.234	1.331
	Fitchburg*	86	8.151	1.677
	Massasoit*	19	7.579	2.912
	MCLA	3	8.000	2.000
	MCC	24	8.208	2.021
	Salem State	40	8.300	1.757
	Westfield	11	8.818	1.079
Process: Once a design has been created using the engineering design process, it is a completed design.	Expert	94	9.383	1.219
	Fitchburg*	86	4.454	2.194
	Massasoit*	19	3.842	2.363
	MCLA*	3	5.000	4.359
	MCC*	24	4.750	2.289
	Salem State*	40	4.200	2.420
	Westfield*	11	3.455	1.508

Pre-Process con't.		N	Mean	Std. Deviation
Process: Testing to failure is important because you can apply the knowledge you gained to your next design.	Expert	94	2.298	1.789
	Fitchburg*	86	8.023	1.872
	Massasoit*	18	8.389	2.330
	MCLA	3	5.000	2.000
	MCC*	24	8.083	2.185
	Salem State*	40	8.525	1.648
	Westfield*	11	8.000	2.324
Process: There is always a definitive right answer.	Expert	93	8.710	1.619
	Fitchburg*	86	3.442	2.404
	Massasoit*	19	3.105	2.622
	MCLA*	3	3.000	2.000
	MCC*	24	2.667	1.685
	Salem State*	40	2.975	2.224
	Westfield*	11	3.818	2.089
Process: There is usually one best way to solve a problem.	Expert	94	1.702	0.948
	Fitchburg*	86	4.058	2.632
	Massasoit*	19	4.053	2.896
	MCLA	3	2.333	2.309
	MCC	24	3.125	2.213
	Salem State*	40	3.275	2.727
	Westfield*	11	4.727	2.370
Process: Thinking of many different ideas for a design is usually a waste of time.	Expert	94	2.957	2.194
	Fitchburg*	86	2.361	1.964
	Massasoit*	19	2.421	2.673
	MCLA	3	1.000	0.000
	MCC	24	2.667	2.548
	Salem State*	40	1.900	1.851
	Westfield*	11	1.909	0.944
Process: Engineers from many different disciplines work together to create a product.	Expert*	94	1.872	1.827
	Fitchburg*	86	7.488	1.845
	Massasoit*	19	7.684	2.335
	MCLA*	3	8.000	1.000
	MCC*	24	7.750	2.691
	Salem State*	40	7.725	1.724
	Westfield*	11	8.091	1.446

Table 6: Post-Test Process

		N	Mean	Std. Deviation
Process: An engineer should test materials before creating a design that uses those materials.	Expert	94	7.383	2.536
	Fitchburg	45	8.422	1.877
	Massasoit	19	9.368	1.165
	MCLA	2	8.500	2.121
	Salem State*	11	10.000	0.000
	Westfield*	11	9.909	0.302
Process: Analysis of data helps engineers make informed design decisions.	Expert	94	9.575	0.769
	Fitchburg*	45	8.244	2.069
	Massasoit	19	9.579	0.607
	MCLA	2	10.000	0.000
	MCC	1	6.000	.
	Salem State	11	9.818	0.603
	Westfield	11	9.636	0.505
Process: Engineering design is an iterative process.	Expert	92	9.239	1.409
	Fitchburg*	45	6.911	2.141
	Massasoit*	19	6.790	3.029
	MCLA	2	8.000	0.000
	Salem State	11	8.727	1.737
	Westfield	11	9.364	1.206
Process: Engineering failures are an important source of engineering knowledge.	Expert	92	9.326	1.130
	Fitchburg*	45	8.356	1.967
	Massasoit	19	8.947	1.353
	MCLA	2	8.500	0.707
	Salem State	11	9.273	1.849
	Westfield	11	9.273	1.009
Process: Engineers don't need to know much about math.	Expert	93	2.075	1.990
	Fitchburg	45	2.289	2.293
	Massasoit	19	1.842	1.642
	MCLA	2	3.000	1.414
	Salem State	11	1.546	1.293
	Westfield	11	2.455	1.753
Process: Engineers often cycle through the engineering design process again and again as they work on a single problem.	Expert	93	9.011	1.371
	Fitchburg*	45	7.778	1.941
	Massasoit	19	8.526	1.541
	MCLA	2	7.000	1.414
	Salem State	11	9.727	0.905
	Westfield	11	8.727	2.649
Process: Engineers often work in teams.	Expert	94	9.340	0.979
	Fitchburg*	45	7.511	2.139
	Massasoit*	19	7.947	1.900
	MCLA	2	8.000	1.414
	Salem State	11	9.636	0.674
	Westfield	11	9.000	1.095

Post-Process con't.		N	Mean	Std. Deviation
Process: Engineers typically work alone.	Expert	94	2.181	1.311
	Fitchburg*	45	3.267	1.876
	Massasoit	19	2.947	1.747
	MCLA	2	4.500	3.536
	Salem State	11	2.364	1.690
	Westfield	11	3.000	2.530
Process: Because engineers use science and math, they almost always get the same answer.	Expert	94	2.309	1.723
	Fitchburg*	45	3.422	2.321
	Massasoit	19	3.211	2.371
	MCLA	2	2.000	0.000
	Salem State	11	3.364	2.541
	Westfield	11	2.636	1.567
Process: Engineers use science in their work.	Expert	94	8.957	1.414
	Fitchburg	45	8.444	2.084
	Massasoit	19	9.158	1.015
	MCLA	2	9.000	0.000
	Salem State	11	9.727	0.647
	Westfield	11	9.455	1.036
Process: Feedback is important to the engineering design process.	Expert	93	9.527	0.746
	Fitchburg*	45	8.333	2.045
	Massasoit	19	9.579	0.838
	MCLA	2	9.500	0.707
	Salem State	11	9.546	1.508
	Westfield	11	8.818	1.328
Process: Innovation and creativity are important to the engineering design process.	Expert	94	9.234	1.331
	Fitchburg*	45	8.089	2.324
	Massasoit	19	9.105	1.197
	MCLA	2	9.500	0.707
	Salem State	11	9.455	1.214
	Westfield	11	8.909	1.300
Process: More than one design may be acceptable for a given problem.	Expert	94	9.489	0.852
	Fitchburg*	45	8.111	2.025
	Massasoit	19	9.211	0.918
	MCLA	2	8.500	0.707
	Salem State	11	9.818	0.603
	Westfield	11	9.273	0.786
Process: Once a design has been created using the engineering design process, it is a completed design.	Expert	94	2.277	1.706
	Fitchburg*	45	3.822	2.570
	Massasoit*	19	3.842	2.794
	MCLA	2	5.500	3.536
	Salem State	11	4.091	2.071
	Westfield	11	3.364	2.157

Post-Process con't.		N	Mean	Std. Deviation
Process: Testing to failure is important because you can apply the knowledge you gained to your next design.	Expert	93	8.742	1.466
	Fitchburg	45	8.000	2.023
	Massasoit	19	8.211	2.371
	MCLA	2	5.500	3.536
	Salem State	11	9.364	1.286
	Westfield	11	8.818	1.079
Process: There is always a definitive right answer.	Expert	94	1.702	0.960
	Fitchburg*	45	2.956	2.099
	Massasoit	19	2.790	1.988
	MCLA	2	4.000	4.243
	Salem State	11	2.727	2.005
	Westfield	11	2.000	1.265
Process: There is usually one best way to solve a problem.	Expert	94	2.979	2.185
	Fitchburg	45	2.933	2.220
	Massasoit	19	3.105	2.258
	MCLA	2	2.500	2.121
	Salem State	11	3.546	2.911
	Westfield	11	2.909	1.758
Process: Thinking of many different ideas for a design is usually a waste of time.	Expert	94	1.787	1.671
	Fitchburg	45	2.200	1.817
	Massasoit	19	1.474	0.697
	MCLA	2	4.000	4.243
	Salem State	11	2.000	2.408
	Westfield	11	2.000	1.265
Process: Engineers from many different disciplines work together to create a product.	Expert	93	8.914	1.340
	Fitchburg*	45	7.489	2.191
	Massasoit	19	8.684	1.336
	MCLA	2	9.000	0.000
	Salem State	11	9.455	1.293
	Westfield	11	8.364	2.203

Table 7: Pre-Test Context

Item	Group	N	Mean	Std. Deviation
Context: Engineers often think about criteria and constraints.	Expert	93	8.957	1.326
	Fitchburg*	86	7.291	2.046
	Massasoit*	19	7.158	2.292
	MCLA	3	7.000	1.732
	MCC*	24	6.958	2.510
	Salem State*	40	7.325	2.280
	Westfield	11	7.727	1.679
Context: Balancing different design variables is an important part of engineering.	Expert	94	9.532	0.826
	Fitchburg*	86	7.698	1.796
	Massasoit*	19	7.684	2.001
	MCLA	3	8.000	1.000
	MCC*	24	7.958	1.574
	Salem State*	40	7.975	1.915
	Westfield*	11	8.364	1.206
Context: Engineering has changed society.	Expert	94	9.638	0.774
	Fitchburg*	86	8.593	1.648
	Massasoit*	19	8.105	2.208
	MCLA*	3	6.000	4.583
	MCC*	24	8.500	1.474
	Salem State*	40	8.700	2.041
	Westfield	11	9.000	1.414
Context: Trade-offs are inherent in engineering design.	Expert	94	9.734	0.706
	Fitchburg*	86	6.116	1.991
	Massasoit*	19	6.053	2.198
	MCLA*	3	5.000	3.606
	MCC*	24	5.792	2.322
	Salem State*	40	6.450	1.880
	Westfield*	11	6.727	1.737
Context: Problem identification is critical to the engineering design process.	Expert	94	9.521	0.786
	Fitchburg*	86	8.128	1.629
	Massasoit*	19	7.790	2.463
	MCLA	3	7.000	2.646
	MCC*	24	8.333	1.633
	Salem State*	40	8.675	1.542
	Westfield	11	8.546	1.214

Table 8: Post-Test Context

Item	Group	N	Mean	Std. Deviation
Context: Engineers often think about criteria and constraints.	Expert	94	9.511	0.839
	Fitchburg*	45	7.067	2.157
	Massasoit*	19	8.053	2.223
	MCLA	2	8.500	0.707
	Salem State	11	9.727	0.647
	Westfield	11	8.636	1.502
Context: Balancing different design variables is an important part of engineering.	Expert	94	9.628	0.776
	Fitchburg*	45	7.489	1.984
	Massasoit	19	8.895	1.410
	MCLA	2	9.500	0.707
	Salem State	11	9.455	0.820
	Westfield	11	8.818	1.250
Context: Engineering has changed society.	Expert	94	9.745	0.702
	Fitchburg*	45	8.667	1.966
	Massasoit	19	9.158	1.463
	MCLA	2	8.000	1.414
	Salem State	11	10.000	0.000
	Westfield	11	9.546	0.522
Context: Trade-offs are inherent in engineering design.	Expert	94	9.543	0.785
	Fitchburg*	45	6.289	1.926
	Massasoit*	19	7.684	2.029
	MCLA	2	8.500	0.707
	Salem State*	11	8.273	1.849
	Westfield	11	7.091	2.071
Context: Problem identification is critical to the engineering design process.	Expert	94	9.489	1.189
	Fitchburg*	45	7.800	2.361
	Massasoit	19	9.105	1.560
	MCLA*	2	5.500	3.536
	Salem State	11	9.273	1.348
	Westfield	11	9.091	1.136

Table 9: Pre-Test Products

Item	Group	N	Mean	Std. Deviation
Products: Technology is rarely a process.	Expert	94	9.394	1.416
	Fitchburg*	86	2.919	2.149
	Massasoit*	19	2.526	1.837
	MCLA*	3	5.333	4.163
	MCC*	24	3.208	2.734
	Salem State*	40	2.675	1.966
	Westfield*	11	1.909	1.044
Products: Technologies usually require the use of electricity.	Expert	94	2.096	1.600
	Fitchburg*	86	6.198	2.190
	Massasoit*	19	6.211	3.011
	MCLA	3	4.667	2.517
	MCC*	24	6.792	2.604
	Salem State*	40	5.175	2.286
	Westfield*	11	6.000	2.757
Products: A technology can be made up of multiple systems.	Expert	94	3.266	2.329
	Fitchburg*	86	7.756	1.762
	Massasoit*	19	7.947	2.013
	MCLA*	3	9.333	1.155
	MCC*	24	8.125	1.825
	Salem State*	40	8.025	1.847
	Westfield*	11	9.182	0.874
Products: Technologies are primarily objects that use electricity.	Expert	92	9.326	1.232
	Fitchburg*	86	5.140	2.132
	Massasoit*	19	6.421	2.893
	MCLA*	3	4.333	1.155
	MCC*	24	6.417	2.394
	Salem State*	40	4.775	2.496
	Westfield*	11	5.364	2.292
Products: Most things in your home were designed by engineers.	Expert	93	2.366	1.768
	Fitchburg*	86	7.651	2.085
	Massasoit*	19	7.579	2.036
	MCLA*	3	6.667	2.887
	MCC*	24	6.875	2.692
	Salem State*	40	7.575	2.123
	Westfield*	11	8.455	1.635
Products: All technologies are physical objects.	Expert	94	8.170	2.312
	Fitchburg*	86	4.663	2.263
	Massasoit*	19	3.737	2.725
	MCLA*	3	3.000	2.000
	MCC*	24	4.667	2.599
	Salem State*	40	3.850	2.237
	Westfield*	11	4.273	2.284

Pre-Products, con't		N	Mean	Std. Deviation
Products: The definition of technology goes beyond electronics.	Expert	94	1.883	1.578
	Fitchburg*	86	8.314	1.724
	Massasoit*	19	8.263	2.491
	MCLA*	3	8.667	1.528
	MCC*	24	8.917	1.472
	Salem State*	40	8.825	1.810
	Westfield*	11	8.636	1.690

Table 10: Post-Test Products

Item	Group	N	Mean	Std. Deviation
Products: Technology is rarely a process.	Expert	94	2.106	1.603
	Fitchburg	45	2.689	2.224
	Massasoit	19	1.632	1.165
	MCLA	2	1.500	0.707
	Salem State	11	1.909	1.300
	Westfield	11	1.636	1.027
Products: Technologies usually require the use of electricity.	Expert	94	3.319	2.324
	Fitchburg*	45	4.978	2.417
	Massasoit*	19	6.158	3.387
	MCLA	2	3.000	1.414
	Salem State	11	4.909	3.048
	Westfield	11	4.818	2.601
Products: A technology can be made up of multiple systems.	Expert	92	9.413	0.879
	Fitchburg*	45	7.556	2.252
	Massasoit	19	8.790	1.475
	MCLA*	2	6.500	0.707
	Salem State	11	9.727	0.647
	Westfield	11	9.182	0.982
Products: Technologies are primarily objects that use electricity.	Expert	93	2.366	1.640
	Fitchburg*	45	4.200	2.332
	Massasoit*	19	5.105	2.998
	MCLA	2	2.500	0.707
	Salem State	11	3.727	3.036
	Westfield*	11	4.546	3.110
Products: Most things in your home were designed by engineers.	Expert	94	8.245	2.188
	Fitchburg	45	8.156	2.067
	Massasoit	19	8.421	1.575
	MCLA	2	8.500	0.707
	Salem State	11	9.455	1.214
	Westfield	11	8.000	2.683

Post-Products, con't.		N	Mean	Std. Deviation
Products: All technologies are physical objects.	Expert	94	1.798	1.333
	Fitchburg*	45	4.711	2.573
	Massasoit*	19	3.316	2.518
	MCLA	2	4.500	3.536
	Salem State*	11	4.182	3.281
	Westfield	11	3.636	2.873
Products: The definition of technology goes beyond electronics.	Expert	93	9.731	0.574
	Fitchburg*	45	8.178	2.114
	Massasoit	19	9.421	0.769
	MCLA	2	10.000	0.000
	Salem State	11	9.909	0.302
	Westfield	11	9.727	0.467

Principal Components Analysis

In this section of the current report, DSRA conducts a preliminary validation study of the engineering judgments survey through the use of a principal components analysis (PCA). In a PCA the responses to the items are analyzed for their correlations with one another, then these correlations are further analyzed to identify “clumped” patterns among these items. For an instrument to be a valid measure of what it is claimed to be measuring, the observed “clumps” should have an obvious relation to the intended factors of the instrument. For the engineering judgments survey, the intended factors are process, context, and products, with each item intended to provide information on the relative accuracy (understood as similarity to expert judgments) in the respondents’ answers. As we have seen, Items 1-19 (Process) should generate a correlative “clump” distinct from Items 20-24 (Context), and from Items 25-31 (Products)

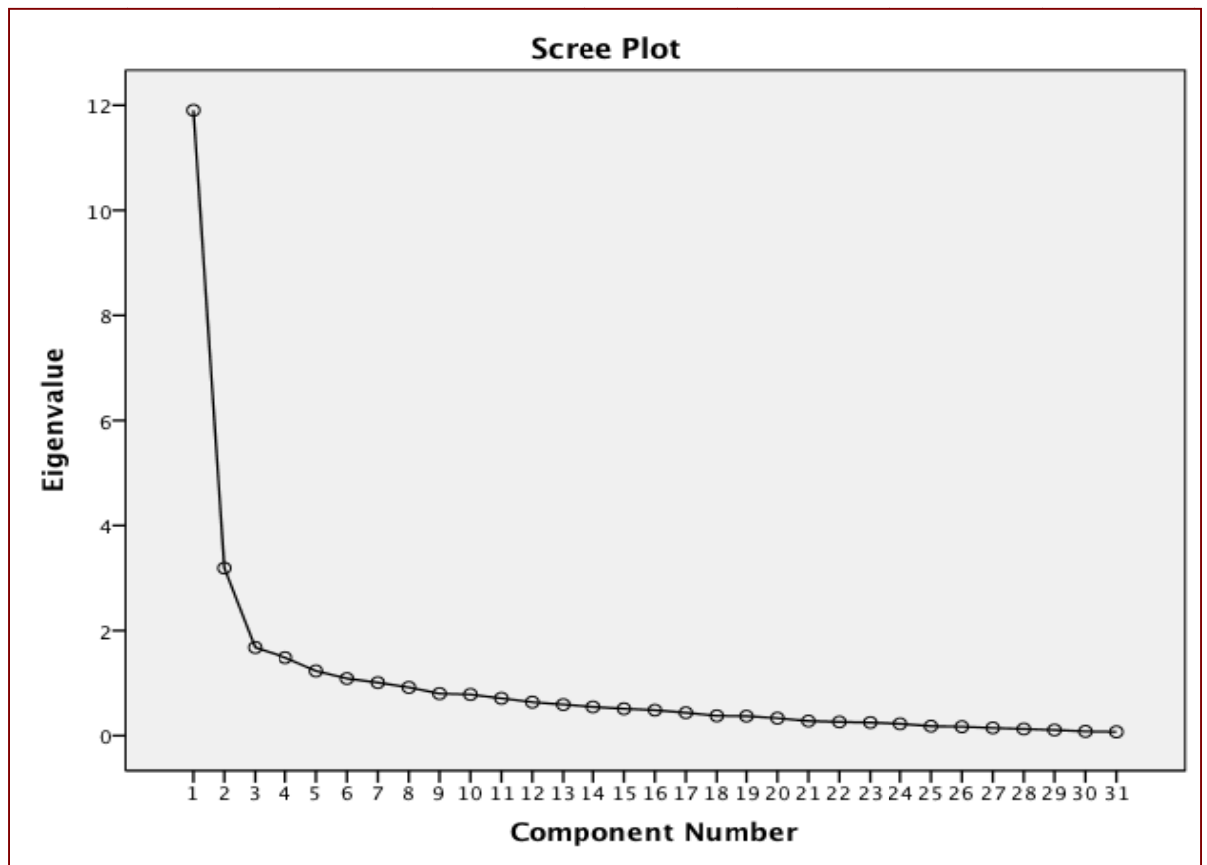
The first step in conducting a PCA is the determination of the adequacy of the sample. For the current series of tests, DSRA used *only* the student post-tests, without including either the expert group or the answers from the faculty from the summer of 2010. The determination of the adequacy of the sample is done through two statistical tests (the KMO & Bartlett), and, as the following table shows, both the high KMO value (this should be above 0.6) and the significant Bartlett value support the finding that the sample is adequate for conducting a PCA.

Table 11: KMO & Bartlett Tests

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.864
Bartlett's Test of Sphericity	Approx. Chi-Square	1759.498
	df	465
	Sig.	.000

The next step in the PCA is the determination of the number of factors in the sample. While the *intended* number of factors is three (domain, context, and products), it could be that the *measured* number of factors (also called “components”) is either more or less than 3. Both an initial factor solution (not shown) and the scree plot below indicate that there are, in fact, three factors in the student post-test responses. The following graphic clearly shows a sharp “elbow” at the 3 point, indicating that this is the number of factors to be examined.

Table 12: Components Distribution



The next step to the PCA is to locate the clumpings among the items, and then see if these measured associations correspond to the intended factors. The following table presents these findings. In a really clean result the Process items would all appear in the Component 1 column and nowhere else, with the Context items in the Component 2 column (and nowhere else), and likewise for the Products items for the Component 3 column.

In the case of the engineering judgments survey, the result is not as clean as one would hope. The somewhat “overpopulated” Component 1 column indicates that there might be a problem with the discriminant validity of the survey items, in other words, the intended concepts are not adequately distinguished in the engineering statements. There are other possible reasons for the crowded Component 1 column. It could be that the survey was administered under varying conditions, with some students responding under more formal circumstances and other students responding in much less formal circumstances. It might also be that the intended factors need to be re-conceptualized to more closely reflect what the instrument measures. Instead, for example of “process,” it could be that we are measuring something rather different, requiring that the project carefully sort through the items and identify those that are most closely related and perhaps discarding others that are not germane to the intended factor. Finally, it could be more surveys need to be done before jumping to any conclusions at all. This final response is not uncommon in validation studies.

In the following table the items marked in yellow form one factor, while the turquoise items form a second, and the unmarked items form a third. One might re-work the factors, for example, with the activity of an engineer being one factor and the results of engineering being another. Some items could possibly be discarded and others, taken from the larger set of expertly-judged items, added to better suit the validity needs of the instrument. In any event, this is an extended process and one that will demand of the project considerable reflection on not only engineering as a set of notions, but also the activities and outcomes of the BEST project.

Table 13: Rotated Component Matrix

Item	Component		
	1	2	3
1. Process: An engineer should test materials before creating a design that uses those materials.	.753		
2. Process: Analysis of data helps engineers make informed design decisions.	.831		
3. Process: Engineering design is an iterative process.	.350		.402
4. Process: Engineering failures are an important source of engineering knowledge.	.779		
5. Process: Engineers don't need to know much about math.			.419
6. Process: Engineers often cycle through the engineering design process again and again as they work on a single problem.	.681		
7. Process: Engineers often work in teams.	.615		-.465
8. Process: Engineers typically work alone.			.714
9. Process: Because engineers use science and math, they almost always get the same answer.		.764	
10. Process: Engineers use science in their work.	.821		
11. Process: Feedback is important to the engineering design process.	.791		
12. Process: Innovation and creativity are important to the engineering design process.	.701		
13. Process: More than one design may be acceptable for a given problem.	.837		
14. Process: Once a design has been created using the engineering design process, it is a completed design.		.653	
15. Process: Testing to failure is important because you can apply the knowledge you gained to your next design.	.622		
16. Process: There is always a definitive right answer.		.750	
17. Process: There is usually one best way to solve a problem.		.654	
18. Process: Thinking of many different ideas for a design is usually a waste of time.	-.378	.470	.405
19. Process: Engineers from many different disciplines work together to create a product.	.758		
20. Context: Engineers often think about criteria and constraints.	.700		
21. Context: Balancing different design variables is an important part of engineering.	.824		
22. Context: Engineering has changed society.	.866		
23. Context: Trade-offs are inherent in engineering design.	.591		
24. Context: Problem identification is critical to the engineering design process.	.737		
25. Products: Technology is rarely a process.	-.402	.578	
26. Products: Technologies usually require the use of electricity.		.394	
27. Products: A technology can be made up of multiple systems.	.700		
28. Products: Technologies are primarily objects that use electricity.		.474	.475
29. Products: Most things in your home were designed by engineers.	.639		
30. Products: All technologies are physical objects.			.570
31. Products: The definition of technology goes beyond electronics.	.740		
Extraction Method: Principal Component Analysis.			
Rotation Method: Varimax with Kaiser Normalization.			
a. Rotation converged in 5 iterations.			

Conclusions & Recommendations

The above data show that the participating faculty were generally quite effective in inculcating in their preservice teachers a stronger sense of what engineering is and of how it fits into the larger world. The striking diminishment of significant disagreement with the expert judgments is a compelling indicator of the faculty having successfully conveyed to their students much of the “mentality” of engineering as conceptualized in the BEST project. The variation among the colleges is curious, however, and the project would do well to characterize what it considers to be the important implementation variables that might help to model these differences.

The PCA of the instrument provides some indication of the limitations of the instrument, however, and care will need to be taken in its future uses. The students taking the survey ought to be instructed to respond with some formality and in a consistent manner. Further, the instrument itself may need further refinement, eliminating some items and substituting others, in an effort to create a valid and generally helpful instrument.

Taking into consideration the above, DSRA recommends the following:

- That the project gather implementation data to help analyze the student-level findings.
- That the project examine the results of the PCA and consider ways that the survey might be improved or that the target factors be more fully characterized.