Evaluation of the ATLAS Program

Final Report

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Executive Summary

The following report summarizes the findings of evaluation activities related to the Boston Museum of Science ATLAS project (as funded by the NSF), which seeks to infuse engineering content largely into preservice teacher preparation programs, including education and science courses enrolled in by both preservice elementary education students and other non-science majors. The findings have been developed by Davis Square Research Associates (DSRA) from surveys of ATLAS participants: one of community college students, two surveys of 4-year college students, and one survey from participating ATLAS faculty. The general focus of the surveys was weighted toward the measurement of attitudinal change, though there was some preliminary development of an instrument for engineering judgments. All surveys were conducted during 2009-2011.

Key findings include:

- Community college students reported significant attitudinal change toward engineering and the incorporation of engineering in their future work in education.
- Responding students reported significant attitudinal gains around engineering as well intentions to continue to use engineering content in their careers
- Students showed modest gains on the engineering judgments survey (EJS).
- Responding faculty members reported significant attitudinal gains around teaching engineering.
- Responding faculty consistently reported intentions to continue to incorporate engineering content in their courses

Sample & Method

Sample

The first table below summarizes the sampling frame for the 2- and 4-year college students who completed a pre-post survey on attitudes toward engineering, while the following table summarizes the sample for the engineering judgments data. The faculty sample for the current report included 11 of 19 ATLAS faculty participants (for a response rate of 58%) from seven Massachusetts two- and four-year colleges.

Table 1: Attitudinal Survey Sample Summarized

		Course Type			
		Education	**Engineering**	**Science**	**Total**
College	Holyoke CC	6	13	0	19
	Westfield State	0	0	12	12
	Bridgewater State	0	0	28	28
	Fitchburg State	17	0	0	17
	NECC	16	0	15	31
Total		39	13	55	107

Table 2: Engineering Judgments Survey by College and Major

		Major		
		Non-Education	**Education**	**Total**
College	FSU	127	51	178
	Westfield	23	23	46
Total		150	74	224

The recruitment of the expert respondents (N=94) to the engineering judgments survey was done through the professional network of the Boston Museum of Science. The institutions at which the experts work range from local high schools to research universities, with most of the expert respondents serving as faculty on the latter. The responses of the expert sample provided a basis for the comparison of the responses of the sample in Table 2.

Method

The three surveys were developed in collaboration with the Boston Museum of Science and administered both on paper and online. Many of the attitudinal questions used a retrospective pre-test model. This model, while having many advantages, does appear to generate somewhat inflated effect sizes. Data from all surveys were downloaded, cleaned, and analyzed by DSRA in SPSS.

The engineering judgment survey relied on an analysis of variance to compare the variances in the responses of the expert sample with the variances in the responses of the treatment sample. The analysis was limited to identifying those items on which there was a significant (or not) difference between the responses of the expert and treatment groups.

The key questions for the evaluation research were:

- How did community college students' attitudes toward engineering change as a consequence of their instructors' participation in ATLAS?
- How did the students at 4-year institutions change in their attitudes toward engineering?
- How did faculty attitudes and related behaviors change as a consequence of participation in the ATLAS project?
- Did students' judgments show less difference from those of the experts on the post-test, as compared to the pre-test?

Survey Findings

The following section of the report is divided into four sections, one for each of the surveys from which the data and analyses are drawn. The first of these is the community college student attitudes survey.

Community College Student Attitudes Survey

In this section DSRA presents the findings by section of the assessment, and then overall. The sections included an opening series of seven Likert scale questions on participant comfort in the teaching and learning of engineering content administered over the 2009-2010 academic year. The other two sections focused on the identification of the work of engineers (3 items) and the correct identification products of engineering (16 items) as opposed to naturally occurring objects (e.g., subways in contrast to dandelions). This instrument is derived from earlier work in the Engineering is Elementary project, and would later undergo considerable revisions to make it more age appropriate for college students.

The following table summarizes the findings from the community college students who responded to the survey (N=65, with 19 from Holyoke Community College and 47 from Northern Essex Community College). The students made significant gains in their reported levels of comfort, with the gains in the other two areas of the assessment falling short of statistical significance. There were no institutional-level between-groups differences in the overall gains among the students, and the effect size was a very large 0.90 for the overall gain. However, there were significant differences between students depending on the type of course in which they enrolled, with students in engineering classes significantly outperforming (ANOVA) their peers in science and education classes. Students enrolled in education courses slightly underperformed relative to students in science classes, though these differences were not significant.

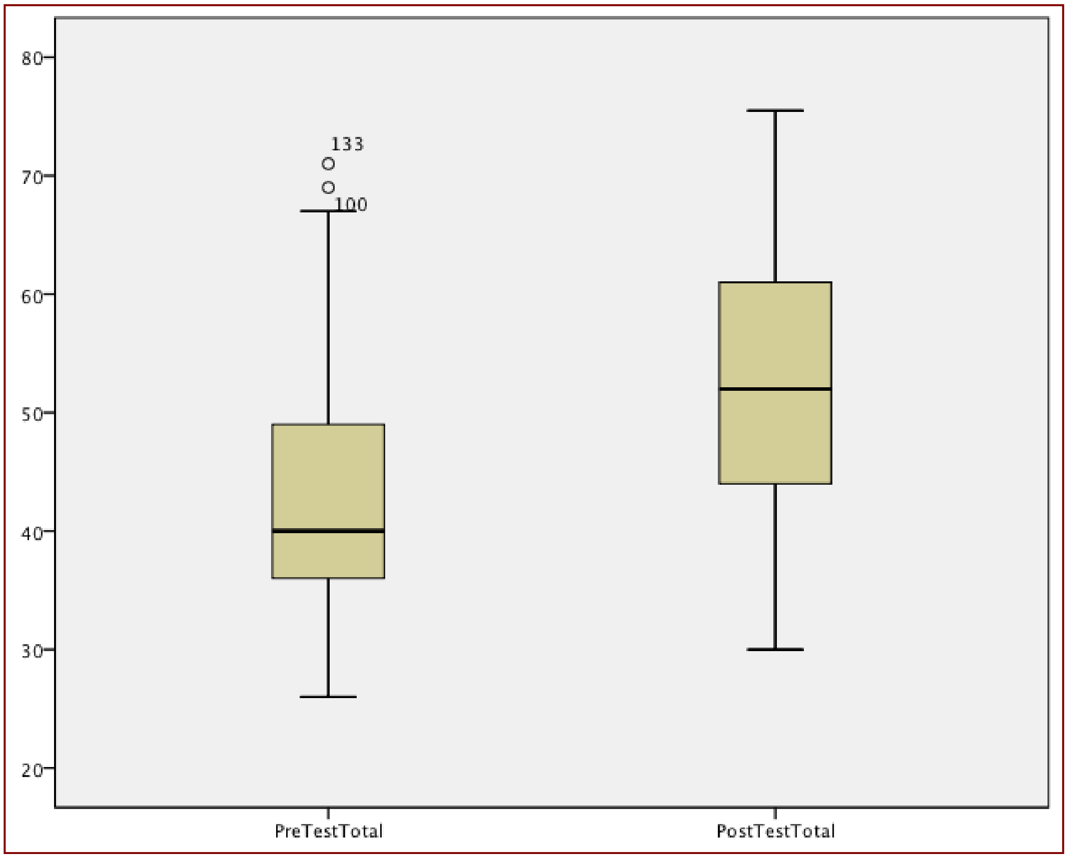
Table 3: Community College Students Pre-Post Summarized

		Mean	**Std. Deviation**
Pair 1*	Pre: Comfort	20.47	8.20
	Post: Comfort	28.28	8.83
Pair 2	Pre: Characterizations	0.87	0.89
	Post: Characterizations	1.05	1.05
Pair 3	Pre: Engineering WorkID	10.40	2.25
	Engineering WorkID	10.71	2.66
Pair 4*	Pre-Test Total	42.65	10.58
	Post-Test Total	52.69	11.60

*Significant at p<.05 (paired samples t test)

The following figure illustrates the overall pre-post gains. The small circles above the pre-test boxplot show two outliers (students 100 and 133). Both the pre-test, post-test, and overall gain scores were normally distributed (Kolmogorov-Smirnov), meaning that some students were more prepared than others. The pre-test scores were a significant (forward stepwise regression) predictor of the post-test scores, as well as the overall gains. These findings indicate that students who were better prepared generally tended to benefit more than their less-prepared colleagues.

Figure 1: Community College Students Pre-Post



When looking at the indicators provided by the project on the strength of implementation (as judged by the ATLAS team), DSRA found that there was a significant effect on the overall gains, accounting for roughly 25% of the measured variance. This variation occurred at the level of the instructor and not at the institutional level, likely an artifact of the considerable latitude the participants enjoyed in their implementation choices.

The above findings are generally consistent with effects previously reported in earlier evaluation reports for ATLAS. Students generally, though not invariably show strong gains on the assessment and this, we hold, is a powerful testament to the effectiveness of the project. On the other hand, between-group differences persist and these appear to occur at the level of the individual instructor. When differences do emerge, these tend to be concentrated in the areas more closely related to the work of engineering, rather than the consistently high attribution of the value of using engineering projects in the classroom.

There are many possible reasons for this variance. Some instructors may have stronger backgrounds, or greater levels of confidence in facilitating student engineering projects. Some may work in contexts that are more supportive either in terms of resources (including time) or material support. There may be differing expectations for student learning, or the students themselves may present varying personal goals that are more or less supportive of doing engineering. In any event, the central point here is that the introduction of engineering content into the community college preservice curriculum can bring about consistently positive attitudinal change across institutional settings, and that these attitudinal changes may vary in terms of their correlative association with cognitive gains.

Four-Year College Student-Level Indicators

In this section DSRA presents the data from the two student surveys, first a modified student attitudinal survey and then the data from the "thinking like an engineer" instrument (EJS). Both data sets rely on students from two 4-year colleges that participated in ATLAS.

Student Attitudinal Change

Turning to the students from two four-year schools, Westfield State and Fitchburg State (N=73), DSRA developed a more extensive attitudinal survey to explore student attitudes toward the field of engineering, self-efficacy around engineering, and the future place of engineering in their professional lives. The first of these is presented in the following table, with all items significant (Wilcoxon), minimally changing standard deviations, and a fairly robust effect size of 0.51 (eta squared).

Table 4: Student Attitudes toward Engineering

		Mean	N	Std. Deviation
Pair 1	I like to learn about engineering - BEFORE	2.81	73	1.54
	I like to learn about engineering - AFTER	4.00	73	1.47
Pair 2	I like to think about engineering - BEFORE	2.63	73	1.44
	I like to think about engineering - AFTER	3.67	73	1.42
Pair 3	I notice engineering in the news - BEFORE	2.62	73	1.54
	I notice engineering in the news - AFTER	3.60	73	1.62
Pair 4	I like to talk about engineering - BEFORE	2.36	73	1.53
	I like to talk about engineering - AFTER	3.26	73	1.62
Pair 5	**Attitude to Engineering - PRE**	10.41	73	5.39
	Attitude to Engineering - POST	14.53	73	5.24

Likewise the six items exploring self-efficacy all showed significant (Wilcoxon) gains, with an overall effect size of 0.53.

Table 5: Student Self-Efficacy toward Engineering

		Mean	**N**	**Std. Deviation**
Pair 1	I feel like I can learn more about engineering - BEFORE	3.38	73	1.66
	I feel like I can learn more about engineering - AFTER	4.32	73	1.33
Pair 2	I feel like I can be good at engineering - BEFORE	2.68	73	1.49
	I feel like I can be good at engineering - AFTER	3.82	73	1.57
Pair 3	I feel like I will benefit from learning more about engineering - BEFORE	3.03	73	1.49
	I feel like I will benefit from learning more about engineering - AFTER	4.32	73	1.40
Pair 4	I admire people who are in engineering - BEFORE	3.70	73	1.60
	I admire people who are in engineering - AFTER	4.73	73	1.42
Pair 5	I think about pursuing further study in engineering - BEFORE	2.11	64	1.51
	I think about pursuing further study in engineering - AFTER	2.84	64	1.65
Pair 6	I think about how engineering will fit into my career - BEFORE	2.26	73	1.38
	I think about how engineering will fit into my career - AFTER	3.51	73	1.66
Pair 7	**Self-Efficacy - PRE**	16.69	64	6.72
	Self-Efficacy - Post	23.30	64	6.61

With the third set of attitudinal items, DSRA found much the same patterns in the responses, with all items significant (Wilcoxon) and an effect size of 0.59

Table 6: Attitudes toward Professional Place of Engineering

		Mean	N	Std. Deviation
Pair 1	I pay attention to the place of engineering in society - BEFORE	2.55	74	1.49
	I pay attention to the place of engineering in society - AFTER	3.73	74	1.49
Pair 2	I feel like I can help children to learn about engineering - BEFORE	2.44	52	1.46
	I feel like I can help children to learn about engineering - AFTER	3.96	52	1.37
Pair 3	I feel like I can guide children through a class engineering project - BEFORE	2.47	51	1.50
	I feel like I can guide children through a class engineering project - AFTER	4.10	51	1.60
Pair 4	I think my students will have a good awareness of engineers - BEFORE	2.60	52	1.54
	I think my students will have a good awareness of engineers - AFTER	3.85	52	1.36
Pair 5	I think my students will have little knowledge of engineering - BEFORE	2.88	52	1.69
	I think my students will have little knowledge of engineering - AFTER	3.33	52	1.69
Pair 6	I think my students will not be able to learn the vocabulary they will need to do class engineering projects - BEFORE	2.77	52	1.60
	I think my students will not be able to learn the vocabulary they will need to do class engineering projects - AFTER	3.38	52	1.72
Pair 7	I think my students will enjoy doing class engineering projects - BEFORE	3.31	52	1.50
	I think my students will enjoy doing class engineering projects - AFTER	4.65	52	1.41
Pair 8	I think my students will learn a lot from doing class engineering projects - BEFORE	3.40	52	1.68
	I think my students will learn a lot from doing class engineering projects - AFTER	4.87	52	1.25
Pair 9	**Attitude to Teaching Engineering - PRE**	22.37	51	9.74
	Attitude to Teaching Engineering - POST	32.06	51	8.71

Summing the above DSRA found the overall student attitudinal changes to be significant (paired samples t test), with an effect size of 0.65 (robust). The correlation between the pre- and post-test values was significant (Pearson, 0.66), indicating that students with better entering attitudes reported better exiting attitudes. However, pre-test attitudes were negatively correlated with overall attitudinal gains (Pearson, -0.48), meaning that students who came in with already strongly positive attitudes reported smaller gains than did students who came in with worse attitudes.

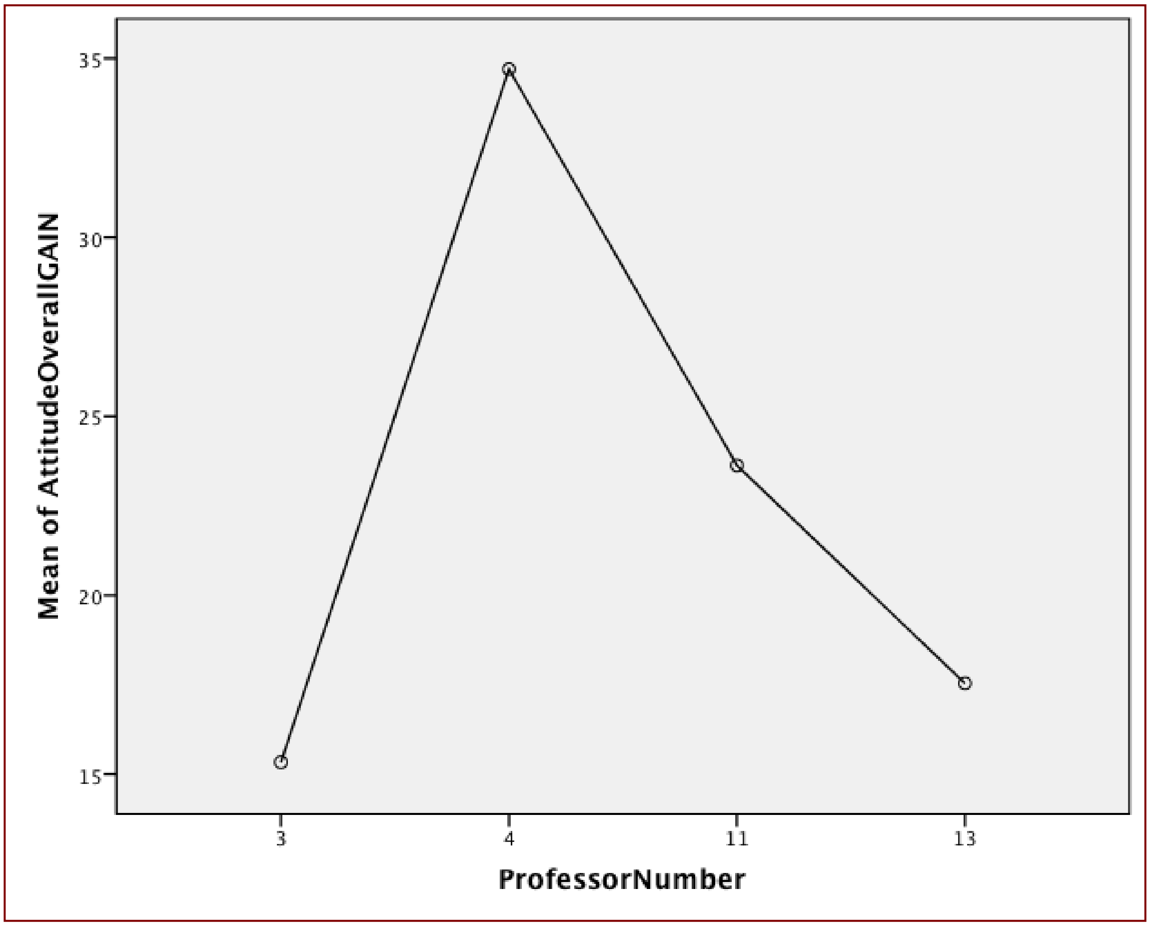
Table 7: Overall Student Attitudinal Change

	Mean	N	Std. Deviation
Attitude Overall PRE	47.93	42	22.12
Attitude Overall POST	71.71	42	20.61

Looking at the distributions of the gains from pre- to post-test, DSRA found that the overall gains were normally distributed (Kolmogorov-Smirnov), meaning that some students gained more than others. Taking this point in combination with the previous, it seems likely that students who tended to report lower values tended to show greater gains, though these gains may be attributable to more than simply low pre-test scores. For example, it could be that there are college-level or professor-level differences that might help account for the observed variance in the attitudinal gain scores.

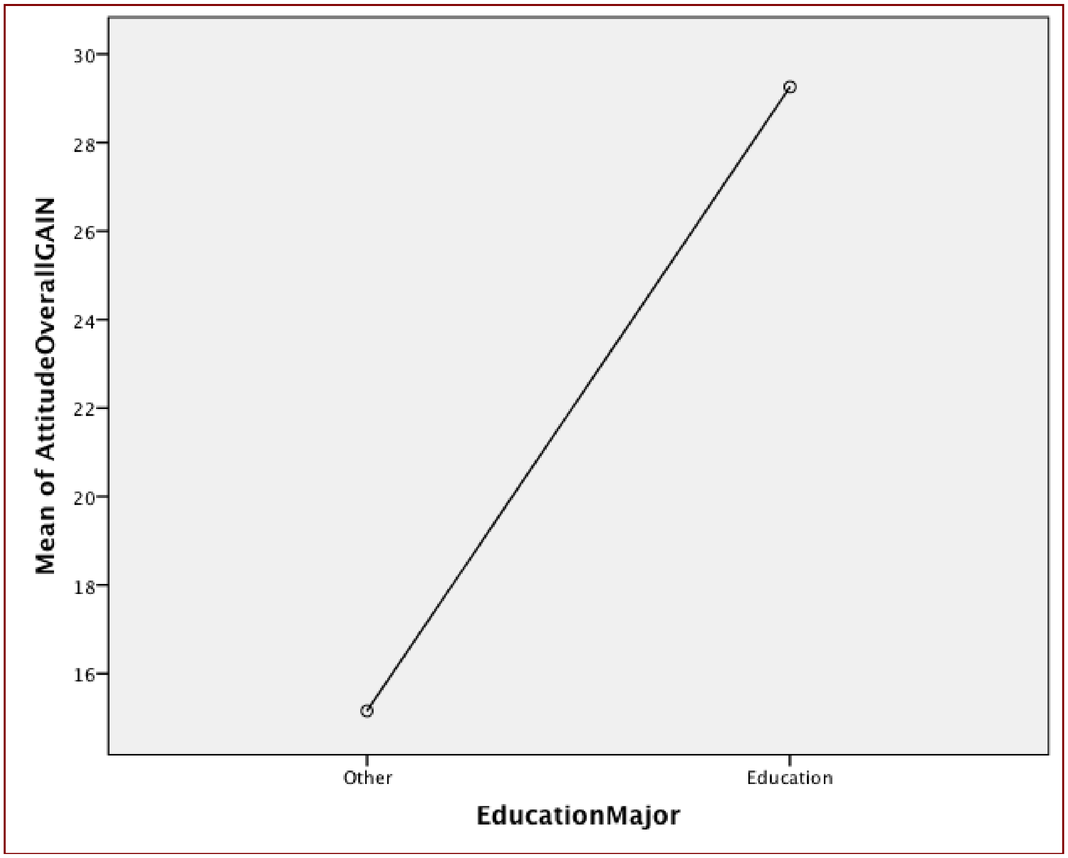
Exploring this point, DSRA compared the gain scores between various groups disaggregated by college, professor, and major (education and non-education). While there were no significant differences between the students of the two colleges, there were differences by professor and major (ANOVA), with one professor's students doing much better than those of other professors, and education majors reporting significantly better attitudinal gains in comparison with their fellows in other majors. This finding may recall what was presented above with the community college student data, namely, that the instructor exerts a critical influence over the student gains.

Figure 2: Student Attitudinal Gains by Professor



The following graphic compares the attitudinal gain scores between education majors and their peers who are majoring in other disciplines. These differences were found to be significant (ANOVA).

Figure 3: Student Attitudinal Gains by Major



Overall, the three factors of college, professor and major accounted for roughly 19% (forward stepwise regression) of the variance seen in the overall gain. This is a rather low value, indicating that over 80% of the pre-post attitudinal change is due to other considerations that are not currently available.

Student Thinking about Engineering

In this section DSRA presents the findings from the survey meant to examine the extent to which the respondents come to respond to statement about engineering in ways that approximate the responses of engineering experts. This survey is composed of 31 items divided into three sections. The three sections are process, context, and products. In this section DSRA looks at each section in turn. The somewhat larger student sample is due to the survey having been administered over two years, as opposed to the single administration of the attitude survey.

In the following table (as well as for all of the following) the items in which there was *no* significance (ANOVA) between the experts and the students are highlighted in yellow. Note that on only one item do the students and experts agree.

Table 8: Process Pre-Test

		N	Mean
Process: An engineer should test materials before creating a design that uses those materials.	Expert	94	7.41
	Fitchburg	86	8.27
	Westfield	11	9.45
Process: Analysis of data helps engineers make informed design decisions.	Expert	94	7.44
	Fitchburg	86	8.38
	Westfield	11	9.36
Process: Engineering design is an iterative process.	Expert	94	9.55
	Fitchburg	86	6.72
	Westfield	11	8.09
Process: Engineering failures are an important source of engineering knowledge.	Expert	92	9.24
	Fitchburg	86	8.07
	Westfield	11	8.55
Process: Engineers don't need to know much about math.	Expert	92	9.24
	Fitchburg	86	2.13
	Westfield	11	1.45
Process: Engineers often cycle through the engineering design process again and again as they work on a single problem.	Expert	93	2.17
	Fitchburg	86	7.52
	Westfield	10	7.90
Process: Engineers often work in teams.	Expert	93	9.04
	Fitchburg	86	7.40
	Westfield	10	8.20
Process: Engineers typically work alone.	Expert	94	9.27
	Fitchburg	86	3.79
	Westfield	11	3.00
Process: Because engineers use science and math, they almost always get the same answer.	Expert	94	2.18
	Fitchburg	86	3.83
	Westfield	11	4.00
Process: Engineers use science in their work.	Expert	94	2.40
	Fitchburg	86	8.49
	Westfield	11	9.09
Process: Feedback is important to the engineering design process.	Expert	94	8.98
	Fitchburg	86	8.22
	Westfield	11	8.82
Process: Innovation and creativity are important to the engineering design process.	Expert	93	9.54
	Fitchburg	85	8.07
	Westfield	11	8.55
Process: More than one design may be acceptable for a given problem.	Expert	94	9.23
	Fitchburg	86	8.15
	Westfield	11	8.82

Pre-Test Process Items (con't)		N	Mean
Process: Once a design has been created using the engineering design process, it is a completed design.	Expert	94	9.38
	Fitchburg	86	4.45
	Westfield	11	3.45
Process: Testing to failure is important because you can apply the knowledge you gained to your next design.	Expert	94	2.30
	Fitchburg	86	8.02
	Westfield	11	8.00
Process: There is always a definitive right answer.	Expert	93	8.71
	Fitchburg	86	3.44
	Westfield	11	3.82
Process: There is usually one best way to solve a problem.	Expert	94	1.70
	Fitchburg	86	4.06
	Westfield	11	4.73
Process: Thinking of many different ideas for a design is usually a waste of time.	Expert	94	2.96
	Fitchburg	86	2.36
	Westfield	11	1.91
Process: Engineers from many different disciplines work together to create a product.	Expert	94	1.87
	Fitchburg	86	7.49
	Westfield	11	8.09

In contrast, DSRA found four items of the 19 process items to show no significant differences on the post-test.

Table 9: Process Post-Test

		N	Mean
Process: An engineer should test materials before creating a design that uses those materials.	Expert	94	7.38
	Fitchburg	106	8.46
	Westfield	37	9.51
Process: Analysis of data helps engineers make informed design decisions.	Expert	94	9.57
	Fitchburg	106	8.24
	Westfield	37	9.16
Process: Engineering design is an iterative process.	Expert	92	9.24
	Fitchburg	106	6.97
	Westfield	37	8.41
Process: Engineering failures are an important source of engineering knowledge.	Expert	92	9.33
	Fitchburg	106	8.48
	Westfield	37	8.76
Process: Engineers don't need to know much about math.	Expert	93	2.08
	Fitchburg	106	2.34
	Westfield	37	2.43
Process: Engineers often cycle through the engineering design process again and again as they work on a single problem.	Expert	93	9.01
	Fitchburg	106	7.84
	Westfield	37	8.46
Process: Engineers often work in teams.	Expert	94	9.34
	Fitchburg	106	7.72
	Westfield	37	8.38
Process: Engineers typically work alone.	Expert	94	2.18
	Fitchburg	106	3.37
	Westfield	37	3.08
Process: Because engineers use science and math, they almost always get the same answer.	Expert	94	2.31
	Fitchburg	106	3.42
	Westfield	37	2.46
Process: Engineers use science in their work.	Expert	94	8.96
	Fitchburg	106	8.51
	Westfield	37	9.24
Process: Feedback is important to the engineering design process.	Expert	93	9.53
	Fitchburg	106	8.45
	Westfield	37	8.65
Process: Innovation and creativity are important to the engineering design process.	Expert	94	9.23
	Fitchburg	106	7.97
	Westfield	37	8.57
Process: More than one design may be acceptable for a given problem.	Expert	94	9.49
	Fitchburg	106	8.13
	Westfield	37	8.95

Post-Test Process Items (con't)		N	Mean
Process: Once a design has been created using the engineering design process, it is a completed design.	Expert	94	2.28
	Fitchburg	106	3.75
	Westfield	37	3.38
Process: Testing to failure is important because you can apply the knowledge you gained to your next design.	Expert	93	8.74
	Fitchburg	106	8.22
	Westfield	37	8.51
Process: There is always a definitive right answer.	Expert	94	1.70
	Fitchburg	106	2.95
	Westfield	37	2.11
Process: There is usually one best way to solve a problem.	Expert	94	2.98
	Fitchburg	106	2.94
	Westfield	37	3.22
Process: Thinking of many different ideas for a design is usually a waste of time.	Expert	94	1.79
	Fitchburg	106	2.08
	Westfield	37	2.14
Process: Engineers from many different disciplines work together to create a product.	Expert	93	8.91
	Fitchburg	106	7.61
	Westfield	37	8.03

For the five context items, DSRA found no significant changes in the pre-post survey responses of the students. Students consistently undervalued the statements relative to the expert judgments.

Table 10: Context Pre-Test

		N	Mean
Context: Engineers often think about criteria and constraints.	Expert	93	8.96
	Fitchburg	86	7.29
	Westfield	11	7.73
Context: Balancing different design variables is an important part of engineering.	Expert	94	9.53
	Fitchburg	86	7.70
	Westfield	11	8.36
Context: Engineering has changed society.	Expert	94	9.64
	Fitchburg	86	8.59
	Westfield	11	9.00
Context: Trade-offs are inherent in engineering design.	Expert	94	9.73
	Fitchburg	86	6.12
	Westfield	11	6.73
Context: Problem identification is critical to the engineering design process.	Expert	94	9.52
	Fitchburg	86	8.13
	Westfield	11	8.55

Table 11: Context Post-Test

		N	Mean
Context: Engineers often think about criteria and constraints.	Expert	94	9.51
	Fitchburg	106	7.21
	Westfield	37	8.27
Context: Balancing different design variables is an important part of engineering.	Expert	94	9.63
	Fitchburg	106	7.57
	Westfield	37	8.46
Context: Engineering has changed society.	Expert	94	9.74
	Fitchburg	106	8.58
	Westfield	37	9.11
Context: Trade-offs are inherent in engineering design.	Expert	94	9.54
	Fitchburg	106	6.29
	Westfield	37	6.54
Context: Problem identification is critical to the engineering design process.	Expert	94	9.49
	Fitchburg	106	7.92
	Westfield	37	8.70

Finally, with the seven items meant to explore judgments around the products of engineering, DSRA found the students moving from significant differences with experts on all seven items to significant differences on 5, a reduction of about 29%.

Table 12: Products Pre-Test

		N	Mean
Products: Technology is rarely a process.	Expert	94	9.39
	Fitchburg	86	2.92
	Westfield	11	1.91
Products: Technologies usually require the use of electricity.	Expert	94	2.10
	Fitchburg	86	6.20
	Westfield	11	6.00
Products: A technology can be made up of multiple systems.	Expert	94	3.27
	Fitchburg	86	7.76
	Westfield	11	9.18
Products: Technologies are primarily objects that use electricity.	Expert	92	9.33
	Fitchburg	86	5.14
	Westfield	11	5.36
Products: Most things in your home were designed by engineers.	Expert	93	2.37
	Fitchburg	86	7.65
	Westfield	11	8.45
Products: All technologies are physical objects.	Expert	94	8.17
	Fitchburg	86	4.66
	Westfield	11	4.27
Products: The definition of technology goes beyond electronics.	Expert	94	1.88
	Fitchburg	86	8.31
	Westfield	11	8.64

Table 13: Products Post-Test

		N	Mean
Products: Technology is rarely a process.	Expert	94	2.11
	Fitchburg	106	2.56
	Westfield	37	2.08
Products: Technologies usually require the use of electricity.	Expert	94	3.32
	Fitchburg	106	4.69
	Westfield	37	4.84
Products: A technology can be made up of multiple systems.	Expert	92	9.41
	Fitchburg	106	7.69
	Westfield	37	8.49
Products: Technologies are primarily objects that use electricity.	Expert	93	2.37
	Fitchburg	106	3.87
	Westfield	37	4.81
Products: Most things in your home were designed by engineers.	Expert	94	8.24
	Fitchburg	106	8.10
	Westfield	37	7.95
Products: All technologies are physical objects.	Expert	94	1.80
	Fitchburg	106	4.44
	Westfield	37	3.86
Products: The definition of technology goes beyond electronics.	Expert	93	9.73
	Fitchburg	106	8.39
	Westfield	37	9.35

Summarizing the above, the students disagreed with the experts on 30 of the 31 items on the pre-test and 25 items on the post-test, a modest reduction of about 17%. This finding is usefully compared with the very strong attitudinal gains, as it seems as though there is some asymmetry between the reported attitudinal gains and the cognitive gains as measured by the engineering judgments survey (EJS). There are a number of possible interpretations for this finding, perhaps beginning with the engineering judgments survey itself. This instrument is still under development and has not been fully validated.

DSRA then conducted a principal components analysis of the EJS (not included herein), which found that the survey was in fact generating factors that closely mirrored the intentions of the survey designers. In other words, the responses of the survey takers generated patterns that tended to converge around the target domains and to remain distinct from one another. While the target components predicted about 60% of the variance (a good, but not excellent finding), the overall breakdown of the data was very promising, indicating that the survey is doing a good job of measuring what it is intended to measure.

A second possibility may be that the faculty are implementing a version of engineering that, while it clearly resembles "normal" engineering in many ways, differs in unknown ways and with unknown importance from the professional version of engineering. DSRA hastens to observe that we make not claim that one version of engineering is better or worse than other, but rather there is some indication on the data that the version of engineering that the faculty are implementing may vary in important ways from the standard version expressed in the judgments of the engineering professionals. It may be worth recalling that in the earlier work with community college students, DSRA encountered a fairly pronounced difference between the very strong attitudinal gains and the more modest gains in learning about engineering.

Faculty-Level Indicators

The faculty began the survey with an open-ended question, asking them to reflect briefly on what participation in ATLAS has meant to them. The responses were uniformly positive, with a general break between those that references pedagogical gains and those that seemed to indicate content area gains. The following table provides examples of what the faculty wrote.

Table 14: Examples of Faculty Responses to Participation in ATLAS

Pedagogical	Content
• It is hard to quantify at this point, but my involvement with ATLAS has certainly inspired me to require more active participation from my students in designing and assembling laboratory experiments. • The experience is quite valuable as it gives me an opportunity to consider how future teachers are learning and also how to present the material so that they can present it in future classrooms • Highly valuable for teaching me and my students about what engineering lessons can look like for elementary students. • Participation provided me with value for my time, limited in scope immeasurable in quantity. The value can be defined as an increase in my skill in presenting science concepts to students.	• The ATLAS project has been extremely important. It has lead to the development of new curriculum to better service our future teachers. • The experience is quite valuable as it gives me an opportunity to consider how future teachers are learning and also how to present the material so that they can present it in future classrooms • An excellent experience - I have incorporated engineering into my methods courses, networked with sister institutions, and have benefited from the resources made available to me throughout the years.

Over the various iterations of the Engineering is Elementary development and dissemination, DSRA compiled an extensive list of typical teacher responses to various aspects of the project, without, however, measuring the distribution of these various points of view. The next four survey questions presented the faculty with four sets of five statements and asked the respondents which statement came closest to expressing their opinions. The statements do not express any particular ordination of judgments, though there is frequently the suggestion of some continuity between one statement and another. In other words, while there may be some hint of ordination, the data should be considered as nominal.

For the first set of questions, the respondents were asked about the place of engineering in their students' education. The distribution here shows that over half saw engineering as helpful in supporting the learning of other content.

Table 15: Value of Engineering

Which of the following best expresses your ideas about the value of engineering in your students' education?			
	Frequency	Percent	Cumulative Percent
Engineering is the best way to make other subject matter learning more interesting.	2	18.2	18.2
Engineering is the best way to introduce new concepts from other subject matter.	1	9.1	27.3
The students like the break from normal lessons.	1	9.1	36.4
I think it's useful in that it supports other subject matter learning.	6	54.5	90.9
It's good, but not as important as more basic subject matter.	1	9.1	100.0

In terms of meeting the demands of integrating engineering projects into classes, nearly three-quarters did not characterize time as an important obstacle.

Table 16: Time Needed for Engineering

Which of the following best describes your thinking about what is needed to integrate engineering in your classes?			
	Frequency	Percent	Cumulative Percent
There is more than enough time to do all the engineering we choose.	1	9.1	9.1
There is plenty of time for engineering, but sometimes we need to review other content.	2	18.2	27.3
There is plenty of time for engineering, but we have other "extras" that we need to do as well.	-	-	-
There is adequate time for engineering, but it does take some juggling.	5	45.5	72.7
There is barely time for engineering and we need to struggle to find enough time.	2	18.2	90.9
There is barely time for engineering and it often means taking time away from other areas that we need to cover.	1	9.1	100.0

Respondents were almost equally split between the value of engineering for introducing new concepts that are not unique to engineering and the value of doing classroom engineering projects for practicing concepts learned elsewhere.

Table 17: Integration of Engineering

Which of the following best describes your thinking about how engineering is best integrated with other content?			
	Frequency	Percent	Cumulative Percent
Engineering is a good way to introduce ideas that will be developed elsewhere such as in math or science	5	45.5	45.5
Engineering is a good way to practice ideas first learned in math or science lessons	6	54.5	100.0
Engineering is best done distinct from other lessons, as stand alone projects	-	-	-
Engineering is really helpful when teaching other subject matter	-	-	-
I never use engineering examples when teaching other subject matter	-	-	-
I would like to use more engineering in teaching other content, but it's hard to work it in.	-	-	-

About 2/3 of the respondents did not identify large local obstacles (from among the available choices) to a greater adoption of engineering in their colleges.

Table 18: Obstacles to Dissemination

Which of the following best describes your thinking about what is needed to integrate engineering when there are other changes going on in your college?			
	Frequency	Percent	Cumulative Percent
There is nothing going on at this college that gets in the way of integrating engineering	7	63.6	63.6
We have one other change under way and we need to juggle this with engineering	-	-	-
We have one other change under way and this really creates problems with doing engineering	-	-	-
We have two or more other changes under way, but these don't really affect doing engineering	1	9.1	72.7
We have two or more changes under way and this makes doing engineering a real problem	2	18.2	90.9
We have some changes going on, but these actually support a stronger integration of engineering.	1	9.1	100.0

Summarizing the above, DSRA finds that the faculty see engineering as consistently linked to other content area learning, whether as a means of introduction or as enrichment, extension or practice. Time does not appear to be a large problem, overall, nor do the respondents cite important local impediments to a greater diffusion of engineering in their college.

Faculty Pre-Post Attitudes

In the following series of questions, faculty were asked to reflect in their attitudes around engineering both before joining ATLAS, and then again at the current point in time. The faculty attitudes under consideration here are (1) attitudes toward engineering, (2) attitudes toward their own skills at conducting classroom engineering projects, and (3) attitudes toward the future place of engineering in their teaching. Each of these three sub-domains is presented in order in the following.

The first five pairs of questions asked the respondents about their attitudes toward engineering. All items were found to be significant (Wilcoxon), with an overall effect size of 0.77 (very robust). The effect sizes for the retrospective pre-test questions are frequently somewhat inflated, nevertheless, this is a very positive finding. Note that the standard deviation for the total is cut nearly in half, indicating that the post-test scores showed much less variation than the pre-test ones.

Table 19: Faculty Pre-Post Attitudes toward Engineering

		Mean	N	Std. Deviation
Pair 1	Enthusiasm for teaching engineering projects - BEFORE ATLAS	2.27	11	1.679
	Enthusiasm for teaching engineering projects - CURRENTLY	5.00	11	1.000
Pair 2	Interest in learning more engineering - BEFORE ATLAS	2.45	11	1.916
	Interest in learning more engineering - CURRENTLY	5.00	11	.775
Pair 3	Your commitment to further engineering learning - BEFORE ATLAS	2.27	11	1.489
	Your commitment to further engineering learning - CURRENTLY	4.64	11	1.362
Pair 4	Comfort in teaching engineering projects - BEFORE ATLAS	2.45	11	1.753
	Comfort in teaching engineering projects - CURRENTLY	4.73	11	1.104
Pair 5	**Attitude to Engineering PRE**	9.45	11	6.203
	Attitude to Engineering POST	19.36	11	3.828

As with the previous items, those items related to faculty self-efficacy showed a marked and significant (Wilcoxon) improvement, with a magnitude on the order of 0.77 (eta squared). Again, note the shrinking standard deviations, another positive finding indicating the project was effective at reaching all survey respondents.

Table 20: Faculty Pre-Post Self-Efficacy in Teaching Engineering

		Mean	N	Std. Deviation
Pair 1	Your ability to present engineering in ways your students find engaging - BEFORE ATLAS	2.20	10	1.619
	Your ability to present engineering in ways your students find engaging - CURRENTLY	4.60	10	1.075
Pair 2	Your ability to draw on everyday examples to explain engineering concepts - BEFORE ATLAS	2.91	11	1.973
	Your ability to draw on everyday examples to explain engineering concepts - CURRENTLY	5.27	11	.905
Pair 3	Your ability to spark student interest in engineering - BEFORE ATLAS	2.27	11	1.489
	Your ability to spark student interest in engineering - CURRENTLY	4.73	11	1.009
Pair 4	**Self-Efficacy PRE**	7.20	10	4.756
	Self-Efficacy POST	14.50	10	2.838

In terms of the respondents' attitudes toward the place of engineering in their teaching, all items showed significant (Wilcoxon) improvement, with an effect size of 0.86 (eta squared). These are strongly positive findings that offer some basis for believing that the effects of project participation will endure beyond the lifespan of the project.

Table 21: Faculty Pre-Post Attitudes toward Teaching Engineering

		Mean	**N**	**Std. Deviation**
Pair 1	Your expectations for how interested your students are in engineering - BEFORE ATLAS	1.82	11	1.168
	Your expectations for how interested your students are in engineering - CURRENTLY	4.27	11	1.191
Pair 2	Your expectations for whether students can learn engineering - BEFORE ATLAS	2.27	11	1.421
	Your expectations for whether students can learn engineering - CURRENTLY	4.73	11	.905
Pair 3	Your expectations for how engaged students will be in engineering projects - BEFORE ATLAS	2.45	11	1.214
	Your expectations for how engaged students will be in engineering projects - CURRENTLY	4.64	11	.924
Pair 4	Your ability to incorporate engineering in non-engineering lessons - BEFORE ATLAS	2.09	11	1.446
	Your ability to incorporate engineering in non-engineering lessons - CURRENTLY	4.64	11	.924
Pair 5	Your intentions to incorporate engineering in non-engineering lessons - BEFORE ATLAS	1.91	11	1.221
	Your intentions to incorporate engineering in non-engineering lessons - CURRENTLY	4.55	11	1.128
Pair 6	**Attitude to Teaching Engineering PRE**	8.09	11	4.721
	Attitude to Teaching Engineering POST	22.82	11	3.995

As one might expect, the overall attitudinal change was significant (paired samples t test), with a large effect size (0.82).

Table 22: Faculty Total Attitudinal Change

		Mean	**N**	**Std. Deviation**
Pair 1	**Attitude Total PRE**	24.70	10	15.826
	Attitude Total POST	56.80	10	10.293

When asking about six behavioral indicators of participation effects, DSRA used a six-point Likert scale (from 1="never" to 6="frequently"). The responding faculty varied normally on all but one item, meaning that some teachers engage in the following behaviors more than others. Note that all values are high, and the standard deviations are rather low.

Table 23: Faculty Engineering Behavioral Indicators

	N	**Mean**	**Std. Deviation**
How often you think about engineering concepts when designing lessons	11	4.09	1.45
How often you speak about engineering with colleagues	11	3.73	1.68
How often you speak about engineering education with colleagues	11	3.73	1.56
How often you think about engineering concepts when responding to student questions*	11	3.73	1.35
How often you have encouraged colleagues to participate in engineering professional development	11	3.45	1.37
How often you think about engineering concepts when assessing student work	11	3.45	1.44

*Significant at *p*<.05 (Kolmogorov-Smirnov)

DSRA also asked about the faculty views of impediments to a greater integration of engineering in the respondents' institutions. While the higher values appear to indicate the faculty and curriculum as presenting the greatest challenges, none of the mean values are significant (Kolmogorov-Smirnov), meaning that the perceived impediments varied from college to college. However, to recall the earlier responses around a further integration of engineering, 9 of 11 faculty generally saw no institutional-level challenges that might impede a more extensive integration of engineering. Thus, given the combined survey responses, the biggest challenge to a broader diffusion of engineering at the college level seems to be principally related to the professional development of the faculty, along with complementary curricular revisions that supporting the faculty engineering professional development.

Table 24: Faculty Views of Impediments to a Greater Integration of Engineering

	N	Mean	Std. Deviation
Faculty commitment	11	6.18	0.98
Faculty preparation	11	5.64	1.36
Curriculum fit	11	5.55	1.04
Adequate resources	11	5.18	1.40
Student lack of preparation	11	5.00	2.05
Student attitudes	11	4.36	1.63
College administration	11	3.36	1.80

Conclusions & Recommendations

The foregoing data converge to create a compelling picture of ATLAS project effectiveness. The student-level data are highly promising in the areas related to attitudes, and, we hope, provide some reason for optimism regarding the evolution of a new breed of teacher, one with a more comprehensive view of subject matter inter-relationships and complementarities. Student survey data consistently showed strong gains and large effect sizes, and the data regarding the future uses of engineering projects provide further reasons for a sanguine outlook regarding these young professionals.

The participating faculty consistently report significant and large gains in their attitudes toward engineering for their teaching, as well as increases in their convictions regarding their capabilities at managing engineering projects in their classes. Typically, projects with high degrees of innovation have a more difficult time bringing about sustained effects. However, in the case of ATLAS we see a project that is both innovative (given the weak engineering backgrounds of the participants) and sustained, as seen through the data presented above. Successfully achieving both the implementation of innovative content and engendering what appear to be enduring effects is an accomplishment as unusual as it is remarkable.

The data from the survey used for the community college students and the EJS instrument give pause, however, before going further. There is a longstanding debate among math educators as to whether school math is part of an unbroken continuum leading to the "real" math of mathematicians, or if school math is different undertaking altogether. Superficially, both school and professional math have much in common, though the math incompatibilists claim that the resemblances stop there.

Could it be that engineering education, a relatively new discipline for schools, is about to be going though a similar period of contention? The data clearly show that the students made scant progress in coming closer to thinking like an engineer. The instrument itself, though not in its final revisions, generated very positive results in the principal components analysis. Could it be that the engineering innovation has been more adapted than adopted in order to better fit into tight curricular confines and within the limits of student preparation and expectations? The data are not adequate for building a reasonable answer to the question. However, it may be helpful for the projects drawing on ATLAS to develop not only fidelity of implementation measures, but also measures that examine the fidelity of the instructor's representation of engineering concepts. On the other hand, other project leaders could consider claiming that the Boston Museum of Science engineering content is intentionally and usefully distinct from standard engineering content. In this case, it would be helpful to map out with explicitness the areas of overlap and the ways in which various points may receive different emphases.

Given the foregoing, DSRA recommends that the project consider

- Examine how the diffusion of engineering content occurs under different conditions in different organizations
- Develop fidelity of implementation measures that avoid the typical biases due to social desirability or acquiescence
- Consider writing a paper on the relations between school engineering and professional engineering.