Evaluating the Impact of Engineering is Elementary

Year 2 of Implementation in Minneapolis and Hopkins Public Schools

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Abstract

A novel STEM curriculum, Engineering is Elementary (EiE), is being implemented in Minneapolis and Hopkins public elementary schools with support from the Cargill Foundation. This report presents results from the second year of a four-year study to evaluate EiE’s impact on student learning.

In the first year of the study, third-grade classrooms in one-third of the schools in each district taught with EiE (Lachapelle, Jocz, & Phadnis, 2011); the scope of EiE implementation expanded in the second year (2010-2011) to include all third grades in both districts plus fourth-grade classrooms in 15 schools. Students completed surveys before and after learning with EiE, providing data used to assess changes in student knowledge.

The research study was designed to measure three categories of outcomes. First, the study evaluated changes in students’ attitudes toward (and understanding of) engineering and technology, and whether exposure to engineering concepts made a difference in how well students learned the related science concepts. In addition, Minneapolis schools show an “achievement gap” between mainstream students and other demographic groups, so the research study compared mainstream students with several sub-groups, including students with Individualized Education Programs, students with limited English proficiency, students from low-income households, and student from several racial groups. Finally, the research study looked at whether the in-classroom training provided for some third-grade teachers by science specialists from the Science Museum of Minnesota (SMM) resulted in improved student learning when these teachers taught EiE independently the following year.

The assessments showed the following:

- Students whose educational experience included EiE showed a significant increase in their ability to define “technology.”
- These students also showed significantly increased understanding of science, engineering, and technology concepts.
- The number of students who had a positive attitude about science and engineering--and saw these fields as career choices they might consider--increased significantly after engaging with EiE.
- When engineering was added to classroom instruction, students did learn more about related science topics.
- Although underrepresented minority students and students from low income households scored lower than mainstream students on both pre- and post-EiE assessments, students in these groups still showed a significant increase in their knowledge after engaging with EiE.
- Students whose teachers had previously received in-classroom training from science specialists showed greater improvement in their science knowledge than students whose teachers did not receive this training.
Introduction

This report is an evaluation of the implementation of the Engineering is Elementary (EiE) curriculum in two districts in Minnesota: Minneapolis and Hopkins. It follows and supplements our 2011 report, “An Evaluation of the Implementation of Engineering is Elementary in Fourteen Minneapolis Public Schools” (Lachapelle, Jocz, & Phadnis, 2011).

In the first year of evaluation, as stated in our 2011 report, one-third of schools in Minneapolis and Hopkins were supported by science specialists from the Science Museum of Minnesota (SMM) to implement EiE in the third grade; another third of Minneapolis schools that did not implement EiE instead contributed control data for comparison. We used this data to examine the effect of EiE on students’ ability to answer questions about engineering and related science topics and found that that EiE students improved significantly from pre- to post-assessment as compared to the control group.

In this second year evaluation, we examine student improvement in two grades. In the third grade, all district teachers were expected to implement EiE, and the evaluation examines score changes for students whose teachers were trained by the science specialists from SMM as compared to those whose teachers were trained in a workshop held during the summer. In the fourth grade, one-third of schools from both districts again hosted science specialists from SMM, and we examine student achievement for those students. In coming years, we will similarly compare student performance for teachers trained using the different methods and examine student achievement in each of the third, fourth, and fifth grades. We will also examine the progression over time of students who participate in EiE in multiple grades.

EiE is a supplementary curriculum developed by the Museum of Science, Boston, with the objective of introducing elementary school students to the engineering design process (EDP). Each EiE unit is designed to build on and apply science content through the design and development of a related technology. For example, in the Designing Maglev Systems unit, students use the EDP to design systems for moving toys across a distance; student designs are required to use magnets to levitate above a track and to carry a given weight.

It is important to introduce engineering in the elementary grades, because children’s interests and preferences in different fields of study are already solidified by middle school (Catsambis, 1995). The United States has seen a drop in interest in engineering by American teens in recent decades, with colleges of engineering seeing higher proportions of international enrollees and graduates (Stine & Matthews, 2009). Children in elementary school tend to have little awareness of engineering and little understanding of technology (Lachapelle & Cunningham, 2010). When they are introduced to engineering in elementary school, children have the opportunity to develop an interest in this broad field, learn about the impact of engineers on the world, and consider the possibility of a future in engineering.
Research Questions

Questions to be addressed in this report include:

1. To what extent does student understanding of science and engineering concepts, as represented by assessment scores, improve significantly? In this second year, we focus on student improvement directly, because we do not have a control group which would allow us to examine the effect of treatment (EiE).

2. Do improvements hold across student demographic groups? In this report, as in the first year report, we examine the following demographics: gender, students with and without Limited English Proficiency (LEP), students receiving or not receiving free or reduced-price lunch (FRL) from the National School Lunch Program, students with or without an Individualized Education Program (IEP), and students from different racial groups.

3. Does participation in EiE continue to improve students’ attitudes towards science and engineering now that most students are taught by district teachers?

4. Do students of teachers who had the in-school residency support of science specialists from the Science Museum of Minnesota in the prior school year do better on assessments than students of teachers who did not have this in-school support and were instead trained in a summer workshop? As this is the first year in which district teachers implement EiE, this is the first time we can examine the question of how different modes of training impact their students.
Methodology

Study Design

During the 2010-2011 school year, all elementary schools in the Minneapolis and Hopkins public school districts participated in district-wide roll-out of Engineering is Elementary to 3rd grade classrooms. Third grade teachers implemented one or both of two EiE units: Designing Model Membranes and Seeing Animal Sounds. Many of these 3rd grade teachers had been trained in the 2009-2010 school year (the first year of the project) by science specialists from SMM who spent two weeks co-teaching one of the two EiE units in each 3rd grade classroom at each of 14 schools. These two-week co-teaching sessions were termed “residencies.” In the analysis, we compare the performance of students whose teachers were trained through the SMM residency program versus the remainder whose teachers were trained in a summer workshop only.

In addition to the 3rd grade implementation, 4th-grade teachers from 13 Minneapolis schools and 2 Hopkins schools participated in EiE training for two units: Designing Maglev Systems, which was chosen as a pair to the FOSS science unit Magnetism and Electricity, and Designing Water Filters, which was chosen to be paired with the FOSS science unit Water. Following training during the summer, teachers taught EiE in the 4th grade using the same residency program that had been implemented for the 3rd grade in the first year of the program, only this time in a different set of 15 schools.

Third-grade district rollout and 4th-grade residencies were both new in the second year of the project (in the first year of the project, only 3rd grade residencies were implemented). The decision to begin with 3rd grade residencies in the first year and progress with district-wide rollout in that grade in the following year, as well as residencies in the next older grade each year, was made by the district in collaboration with SMM, in order to facilitate teacher training, materials management, and implementation. Different EiE units were assigned to each grade so that students would not repeat EiE units as they progressed through the grades. Also, EiE units for each grade were chosen to match the science content taught in that grade.

Identical pre- and post-assessments were collected from all 3rd grade students in both districts, as well as from all 4th grade students in the 15 schools participating in residencies. Pre-assessments were administered before the students were exposed to the engineering unit or any related science topic—for the most part, within the first 2 months of the year—and the post-assessments were administered within 2 weeks after the completion of instruction of the related science unit and the engineering unit.
Data Collection

Each student in a given classroom completed either a multiple-choice unit assessment that was related to the specific science topic and the field of engineering associated with the EiE unit taught in their class, or they completed the “What is Technology” assessment and the “Engineering Attitudes” survey. Students were tested twice—once before beginning the science curriculum and/or related EiE unit, and once after instruction was completed—allowing for a test-retest analysis.

The completed assessments were digitized using an OMR scanner and then imported into a Microsoft Access database. These data were then exported to SPSS Statistics version 20, together with student demographic data, for initial analysis.

Reliability Analysis and Scale Construction

Student responses to each question on the unit-specific assessments and the “What is Technology?” assessment were recoded as correct (1) or incorrect (0). A preliminary scale item (All Scale), which was calculated as the sum of all questions (equivalent to the sum of all correct questions), was also computed for each assessment. Data collected from all classrooms were checked for any transcription errors and unusual or missing data by inspecting the means from the All Scale variable for the pre-assessment and post-assessment separately. Data entry and transcription errors were corrected before continuing.

Initial pre- and post-assessment scores were checked separately for internal reliability and factorability by means of reliability analysis and principal component analysis with direct oblimin rotation in SPSS v19.0. Where scales demonstrated sufficient internal reliability, we used principal component analysis to identify which questions grouped together. We anticipated that the items assessing science and engineering objectives would cluster in separate components. Based on these groupings, sub-scales assessing specific science and engineering topics were calculated and again checked for internal reliability.

For the unit assessments, further data cleaning was completed after analysis of reliability of scores, but before beginning analysis. Any student who had missed more than a threshold number of questions on either the pre- or post-assessment—between two and four, depending on the length of the assessment—was excluded from the dataset. All remaining missing responses were replaced with a zero – a coding of “incorrect.” We also excluded any students who were missing demographic information.

All survey and assessment questions can be found in the Appendix.
Methods of Analysis

Our primary research question is whether participation in EiE affects students’ understanding of the engineering learning objectives and related science concepts, as evidenced by changing assessment scores. Using SPSS Statistics version 20, we carried out backward stepwise multiple regression using the post-test scores for each subscale as outcome variables and pre-test scores as covariates. This strategy results in an ANCOVA model, where the pre-assessment is used to adjust treatment effect estimates by controlling for differences in pre-assessment scores between control and treatment samples. Since we are also interested in evaluating whether effects of the curriculum are modified by gender, socioeconomic status (as measured by student participation in the National School Lunch Program), and race/ethnicity, these demographics were also included as independent variables in the analysis. Though we collected data on students’ status as an English language-learner with Limited English Proficiency (LEP) and participation in an Individualized Education Program (IEP), these variables were not included in the analysis because the sample sizes of such students were too small.

In the backward stepwise method of multiple regression, all predictor variables are entered into an ordinary least squares model, and their coefficients are calculated. Each coefficient has a standard error associated with it, which is used to perform a t-test to determine the statistical significance of the coefficient. The least statistically significant predictor variable is removed, and the regression is recalculated. This process is repeated until only statistically significant predictors remain in the model.

After fitting multiple regression models, we calculated Cohen’s $d$ for each demographic or treatment effect by dividing the coefficient of each binary variable by the standard deviation of the residuals of the conditional model. This corresponds with the standard calculation of Cohen’s $d$, in that the coefficient of a binary variable serves as the difference between the means of the two populations, while the standard deviation of the conditional model residuals serves as the pooled standard deviation of the two populations after controlling for any other factors.

For the “Engineering Attitudes” assessment, we wished to analyze specific categories of statements measuring attitudes towards engineers and engineering, scientists and science, math, and jobs involving engineering skills and activities. Due to the specific nature of these categories, we utilized paired t-tests to test for significance.
Results

In this section, we discuss results from analysis of each of the general and unit-specific assessments. Results for each assessment are reported separately.

Results for the “Engineering Attitudes” Evaluation

Survey Design

The “Engineering Attitudes” (EA) survey measures students’ attitudes toward scientists and engineers, toward the fields of science and engineering as career choices, and toward the skills needed to be a scientist or engineer. Figure 19 in Appendix B presents the list of questions used in the survey; the same questions were used in both pre- and post-instruction assessments. Students were asked to rate how strongly they agreed or disagreed with each statement using a scale of 0 to 4, where 0= “Strongly Disagree” and 4= “Strongly Agree.”

Sample: “Engineering Attitudes”

The EA survey sample consisted of 766 students in 29 third and fourth grade classrooms. For analysis, 30.3% (n=232) of the sample was dropped due to missing pre- or post-assessments or missing demographic information. Thus, the final sample for analysis consisted of 534 students. Slightly more than half of the sample is female, and just under half receives free or reduced-price lunch. Students classified as ELL’s make up 14% of the sample, and about a tenth of the students have an IEP. The majority of students in the sample were white or black, with small numbers from other demographics. Table 35 in Appendix A shows the complete demographics.

Results: “Engineering Attitudes”

Although there is not a control group, the analysis of the EA survey allows us to compare EiE students’ responses pre- and post-assessment to examine whether their attitudes regarding the statements improved. Numerical values of the responses (0=“Strongly Disagree” to 4=“Strongly Agree”) were analyzed by paired sample t-test. For 4 of the statements (9, 10, 15, 16), the order of responses was reversed for analysis (such that 0=“Strongly Agree” and 4=“Strongly Disagree”) to better reflect the other statements’ direction of an improved attitude.

Analysis suggests that EiE students’ attitudes improve as measured by several of the statements on the EA survey. Statements with significantly improved responses are presented in Table 1 with relevant statistics, and the distribution of responses is presented in the subsequent figures.
Table 1. Results of T-tests on Engineering Attitude Statements

<table>
<thead>
<tr>
<th>Statement</th>
<th>Pre-Post Mean Change</th>
<th>Std. Err. of the Mean</th>
<th>t-value</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work of scientists and engineers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I think I know what engineers do for their jobs</td>
<td>+.430</td>
<td>.064</td>
<td>-6.725</td>
<td>585</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Scientists help make people's lives better.</td>
<td>+.166</td>
<td>.054</td>
<td>-3.048</td>
<td>579</td>
<td>.002</td>
</tr>
<tr>
<td>Engineers help make people's lives better.</td>
<td>+.429</td>
<td>.059</td>
<td>-7.310</td>
<td>580</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Engineers cause problems in the world.</td>
<td>+.196</td>
<td>.058</td>
<td>-3.392</td>
<td>571</td>
<td>.001</td>
</tr>
<tr>
<td>Relevance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science has nothing to do with real life.</td>
<td>+.271*</td>
<td>.064</td>
<td>-4.236</td>
<td>575</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Math has nothing to do with real life.</td>
<td>+.233*</td>
<td>.063</td>
<td>-3.726</td>
<td>569</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Future careers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I would enjoy being a scientist when I grow up.</td>
<td>+.131</td>
<td>.053</td>
<td>-2.474</td>
<td>585</td>
<td>.014</td>
</tr>
<tr>
<td>I would enjoy being an engineer when I grow up.</td>
<td>+.326</td>
<td>.059</td>
<td>-5.540</td>
<td>584</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Mean change on a scale of 0-4. *These scales were reversed, so a positive change represents a more positive answer to the question.

Figure 1. Student Attitudes about Science and Engineering Fields

"Neutral" responses not depicted:  
"I think I know what engineers do for their jobs." [Pre: 28.98% Post: 20.11%]  
"Scientists help make people's lives better." [Pre: 24.33% Post: 19.09%]  
"Engineers help make people's lives better." [Pre: 32.2% Post: 24.14%]
According to the t-tests, student attitudes about the science and engineering fields and their role in the world increased significantly following participation in EiE. As shown in Figure 1, not only are students more likely to agree that they know what engineers do at work (statement #20 in Figure 19), but they also are more likely to see scientists and engineers as fundamentally helpful to people (statements #16, 17, and 18). The percent of students in each response category shifts towards agreement for statements about the fields of work, particularly for the two statements about engineering.

Students also became more positive about the relevance of science and math. Following participation in EiE, they disagreed significantly more with statements that science and math have “nothing to do with real life” (Figure 2 representing statements #9 and 10 in Figure 19 of Appendix B). Examining the percent of students in response categories, students already feel quite strongly about the relevance of science and math to life, but following the design challenge, fewer students disagree with these statements.

**Figure 2. Student Attitudes about Relevance of Science and Math**

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"Science has nothing to do with real life." [Pre: 10.81% Post: 10.27%]
"Math has nothing to do with real life." [Pre: 8.70% Post: 9.79%]
```
In addition to a better appreciation for science and engineering fields and for the relevance of science and math, students responding to the EA survey also showed significantly greater interest in careers as scientists or engineers (Figure 3 representing statements #1 and 2 in Figure 19 of Appendix B). Particularly for the statement “I would enjoy being an engineer when I grow up,” the proportion of students tended towards stronger agreement on the post-tests as compared to the pre-tests.

**Figure 3. Student Attitudes about Future Careers**

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"I would enjoy being a scientist when I grow up." [Pre: 36.26% Post: 36.11%]
"I would enjoy being an engineer when I grow up." [Pre: 29.12% Post: 32.01%]
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**Summary: “Engineering Attitudes” Evaluation**

Analysis of student data collected by the EA survey suggests that students participating in EiE demonstrate more positive attitudes about science and engineering on post-tests than pre-tests. Students claim to know more about engineering, appear to have a more positive view of scientists and engineers as professions that help people, and more strongly see themselves as pursuing science and engineering careers. Their responses also suggest that following participation in EiE, they believe more strongly in the relevance of math and science.
Results for the “What is Technology?” Evaluation

The “What is Technology?” (WT) survey presents students with a grid of pictures of 20 items and asks them to indicate whether or not each item is an example of technology. This assessment can be found in Appendix B, Figure 20. For more about the development of this survey, see our first-year evaluation report for this project.

Scale Construction: “What is Technology?”

To analyze the WT survey, a scale of all 20 items was used to represent student learning. Tested on the post-tests, the scale had strong reliability (Cronbach’s $\alpha = .861$, $n=508$).

Sample: “What is Technology?”

The WT sample consisted of 831 students in 31 classrooms. Of this group, 38.9% ($n=323$) were dropped due to missing pre- or post-assessments or missing demographic information. The final sample thus consisted of 508 students.

Demographics for the sample can be found in Table 36 of Appendix A. Slightly over half of the sample is female. Students classified as ELL make up 9.3% of the sample, while students with an IEP make up 13.0%. Although the proportion of students with IEPs exceeds 10% in this sample, this was not examined as a variable in analysis of the WT survey to maintain consistency with all other samples, for which this proportion was less than 10%. The majority of students in the sample were white or black, with small numbers from other demographics. For purposes of analysis, racial demographics were combined into bins, with Represented students (White/Asian) making up 58.7% ($n=298$) and Underrepresented students (Black/Hispanic/Other) making up 41.3% ($n=210$).

Results: “What is Technology?”

With no control group, analysis of the WT survey only allows us to compare EiE students’ responses on pre- and post-assessments. The correctly answered items on the picture grid were summed to construct the All Items scale. Individual items were also examined for proportion of students answering correctly.

Backwards step-wise regression of the All Items scale produced a significant model: $F(2,505)=25.926$, $p<.001$. The model does not explain much of the variance, however: 9.0% (Adj. $R^2 = .090$), suggesting that more data—both a larger sample and more variables of interest—should be collected to create a model with higher explanatory power. This model had a standard deviation of the residuals of 1.220. Relevant statistics for the table can be found in Table 2, with group pre- and predicted post-means presented in Table 3 and Figure 4.
Table 2. Summary of Variables in All Items Scale Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE</th>
<th>β</th>
<th>t-value</th>
<th>p-value</th>
<th>Cohen's d</th>
</tr>
</thead>
<tbody>
<tr>
<td>White/Asian</td>
<td>14.612</td>
<td>.745</td>
<td>19.624</td>
<td>&lt; .001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre All Items</td>
<td>.175</td>
<td>.064</td>
<td>.118</td>
<td>2.748</td>
<td>.006</td>
<td>.0143</td>
</tr>
<tr>
<td>Black/Hispanic</td>
<td>-2.175</td>
<td>.350</td>
<td>-.266</td>
<td>-6.211</td>
<td>&lt; .001</td>
<td>-1.782</td>
</tr>
</tbody>
</table>

Table 3. All Items Scale Scores by Statistically Significant Demographic Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-EiE Mean</th>
<th>Predicted Post-Score</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>White/Asian</td>
<td>10.909</td>
<td>16.521</td>
<td>15.031-18.012</td>
</tr>
</tbody>
</table>

Table 2 denoting “reference group.” Predicted post-score calculated using group mean pre-score.

According to the model, students’ scores significantly increased on the All Items scale from pre- to post-tests (p<.001). Pre-assessment scores had a significant positive effect on predicted post-assessment scores (p=.006). In addition, the significant effect of the Black/Hispanic variable suggests that students from these underrepresented groups had significantly lower scores than White and Asian students. As the post-test confidence interval for these students does not cover the group pre-test mean, however, we can still confidently assert that mean scores for this group did increase significantly.

The significance of the All Items scale analysis is reinforced by an examination of individual items, as can be seen in Figure 5, which shows the proportions of students correctly answering each item on the picture grid on pre- and post-tests.
The items from nature shown on the left side of the graph (bird, oak tree, dandelion, and volcano) are recognizable to students as non-technologies even before participating in EiE, and the electronic technologies on the right side (keyboard, MP3 player, game controller, laptop, and cell phone) are similarly understood from the beginning as technologies. The tendency for students on the pre-test to incorrectly identify the non-electronic technologies in the middle of the graph as non-technologies points to a misconception of technology as only those items using electricity. This misconception does not appear nearly as strongly on the post-tests, suggesting that students gain a more accurate and nuanced understanding of technology following participation in EiE.

**Summary: “What is Technology?” Evaluation**

According to analysis of the *What is Technology?* survey, students improve their ability to identify technologies on the post-test, after participation in EiE. Although students in underrepresented racial groups score lower on both assessments, their improvement is still significant. Students gain, in particular, a more accurate understanding of technology as encompassing both electronic and non-electronic human-made products.
Results for the “Designing Maglev Systems” Unit Evaluation

In the EiE unit *The Attraction is Obvious: Designing Maglev Systems*, students are introduced to transportation engineering through the story of Hikaru, a Japanese boy who designs a maglev transportation system as an attraction for his parent’s toy store (Lesson 1). Students improve a model traffic intersection to learn more about the nature of transportation engineering (Lesson 2) and then explore properties of magnets in preparation for their design challenge (Lesson 3). Finally, students use the engineering design process to design, test, and improve a small maglev transportation system to carry pennies from one side of a track to the other (Lesson 4).

The *Designing Maglev Systems* EiE unit was taught in both Minneapolis and Hopkins in the fourth grade. Only classrooms taught by a science specialist resident from the Science Museum of Minnesota participated in this unit during 2009-2010.

Assessment Design: “Designing Maglev Systems”

The *Designing Maglev Systems* assessment was first designed in 2007 in tandem with the development of the unit. It was revised in 2010 for use in this project. The assessment consists of 24 questions about transportation engineering, engineering design, and scientific properties of magnets (Figure 21 in Appendix B). Identical pre- and post-tests were given to students.

Scale Construction: “Designing Maglev Systems”

The scales for the *Designing Maglev Systems* were originally constructed on the basis of factor analyses performed during revision of the assessment. Scales were constructed from a sample of 371 students completing the assessment. For this sample, the same scales were tested for reliability on students’ post-assessments. An All Items scale of all 24 questions was also calculated as the sum of all correct answers.

Results are presented in Table 4. The Engineering scale broke down into two reliable subscales, Design and Transport Engineering, which were used for analysis. Results of these scales, as well as the Properties of Magnets scale, are reported in the Results section.

<table>
<thead>
<tr>
<th>Scale</th>
<th># of Items</th>
<th>Questions</th>
<th>Content Assessed</th>
<th>N</th>
<th>Reliability (Cronbach’s α)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Items</td>
<td>24</td>
<td>1-24</td>
<td>All questions</td>
<td>301</td>
<td>.804</td>
</tr>
<tr>
<td>Engineering</td>
<td>11</td>
<td>2, 3, 5, 10, 17, 19-24</td>
<td>Design and Transport Engineering Scales</td>
<td>326</td>
<td>.723</td>
</tr>
<tr>
<td>Design</td>
<td>6</td>
<td>19-24</td>
<td>Design of maglev systems</td>
<td>335</td>
<td>.632</td>
</tr>
<tr>
<td>Transport Engineering</td>
<td>5</td>
<td>2, 3, 5, 10, 17</td>
<td>Nature of transportation engineering work</td>
<td>344</td>
<td>.685</td>
</tr>
<tr>
<td>Properties of Magnets</td>
<td>13</td>
<td>1, 4, 6-9, 11-16, 18</td>
<td>Science of magnets</td>
<td>323</td>
<td>.726</td>
</tr>
</tbody>
</table>

*Bold* indicates scales reported in results
Sample: “Designing Maglev Systems”

The full sample of data for Designing Maglev Systems consisted of 512 students in 21 fourth grade classrooms. Of this sample, 29.7% (n=152) were dropped due to a missing pre- or post-test, missing demographic information, or filling out fewer than 19 of the 24 questions for either the pre- or post-assessment. The final sample used for analysis consisted of 360 students.

Demographics for this sample are provided in Table 37 of Appendix A. Slightly more than half of the sample was female, and just over a third received free or reduced-price lunch. Students classified as ELL or having an IEP make up less than 10% of the sample each; these variables were therefore excluded from analysis. The majority of students in the sample were White or Black, with small numbers from other demographics. Thus, racial demographics were grouped into two categories for analysis: White/Asian (n=246, 68.3%) and Black/Hispanic (also including Other racial minority students: n=114, 31.7%).

Results: “Designing Maglev Systems”

Due to the lack of a control group, the analysis of Designing Maglev Systems is limited in scope: we were only able to assess whether EiE students did significantly better on post-assessments as compared to pre-assessments and to explore the effect of demographics on this improvement. Student performance on each scale (Table 4) was used as outcome variables, calculated as the number of items answered correctly on each scale. Using backwards step-wise regression, we analyzed the post-assessment scores and several predictor variables, including the pre-assessment score on the given scale (Pre “Scale Name”) and the demographic variables shown in bold in Table 37: Gender (Male), FRL, and Black/Hispanic.

Designing Maglev Systems: Design Scale

The Design scale measured student performance on questions about design and engineering of a maglev transportation system, the unit’s culminating design challenge. The highest score possible on this scale was 6. The backwards step-wise method produced a significant model: $F(3,348)=36.196$, $p<.001$. The model explains 23.1% of the variance (Adjusted $R^2=.231$), and the standard deviation of the residuals was 0.812. Regression coefficients and relevant statistics for each predictor variable included in the final model can be found in Table 5. Scores predicted by the model are summarized in Table 6 and in Figure 6, which depicts mean pre- and predicted post-scores for groups with statistically different effects.

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE</th>
<th>β</th>
<th>t-value</th>
<th>p-value</th>
<th>Cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Reference Group)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White/Asian, Not FRL</td>
<td>3.457</td>
<td>.180</td>
<td>19.241</td>
<td>&lt; .001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre Design</td>
<td>.298</td>
<td>.050</td>
<td>.286</td>
<td>5.967</td>
<td>&lt; .001</td>
<td>0.367</td>
</tr>
<tr>
<td>FRL</td>
<td>-.759</td>
<td>.218</td>
<td>-.759</td>
<td>3.477</td>
<td>.001</td>
<td>-0.934</td>
</tr>
<tr>
<td>Black/Hispanic</td>
<td>-.566</td>
<td>.228</td>
<td>-.156</td>
<td>2.487</td>
<td>.013</td>
<td>-0.697</td>
</tr>
</tbody>
</table>
Table 6. Design Scale Scores by Statistically Significant Demographic Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-EiE Mean</th>
<th>Predicted Post-Score</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>White/Asian, Not FRL</td>
<td>2.884</td>
<td>4.317</td>
<td>3.957-4.677</td>
</tr>
<tr>
<td>White/Asian, FRL</td>
<td>2.743</td>
<td>3.515</td>
<td>2.950-4.081</td>
</tr>
<tr>
<td>Black/Hispanic, Not FRL</td>
<td>2.611</td>
<td>3.669</td>
<td>3.088-4.250</td>
</tr>
<tr>
<td>Black/Hispanic, FRL</td>
<td>2.231</td>
<td>2.797</td>
<td>2.070-3.523</td>
</tr>
</tbody>
</table>

Bold denotes "reference group." Predicted post-score calculated using group mean pre-score.

The model shows evidence that student scores on the Design scale significantly increased from pre- to post-assessment (p<.001). Higher pre-assessment scores had a significant positive effect on pre- to post-test improvement over the reference group (p<.001). There was no significant difference in performance between girls and boys. Although students receiving FRL and those in underrepresented racial demographics had significantly lower scores than those in the reference group (see Table 5 p-values), neither group’s 95% confidence interval includes the pre-mean, meaning it is likely that these students’ scores improved significantly. Students who fall in both of these demographic categories (Black/Hispanic and FRL) may not experience significant change, as the CI does cover the group’s pre-mean, but this effect may be over-emphasized due to high correlation between the FRL and Black/Hispanic variables (r=.660).

Designing Maglev Systems: Transport Engineering Scale

The Transport Engineering scale features questions about the types of work done by transportation engineers, measured on a scale of 0-5. The model derived by regression was significant (F(3,353)=19.786, p<.001) and explains 13.7% of the variance (Adj. R²=.137) with a
.602 standard deviation of the residuals. Relevant statistics are presented in Table 7 and Table 8 and a visual summary can be found in Figure 7.

### Table 7. Summary of Variables in Transport Engineering Scale Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE B</th>
<th>β</th>
<th>t-value</th>
<th>p-value</th>
<th>Cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Reference Group)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White/Asian, Not FRL</td>
<td>2.992</td>
<td>.129</td>
<td>23.109</td>
<td>&lt;.001</td>
<td>0.424</td>
<td></td>
</tr>
<tr>
<td>Pre Transport Engineering</td>
<td>.255</td>
<td>.067</td>
<td>.187</td>
<td>3.803</td>
<td>&lt;.001</td>
<td>0.424</td>
</tr>
<tr>
<td>FRL</td>
<td>-.531</td>
<td>.220</td>
<td>-.160</td>
<td>-2.418</td>
<td>.016</td>
<td>-0.882</td>
</tr>
<tr>
<td>Black/Hispanic</td>
<td>-.686</td>
<td>.228</td>
<td>-.199</td>
<td>-3.008</td>
<td>.003</td>
<td>-1.14</td>
</tr>
</tbody>
</table>

**Bold** denotes “reference group.” Predicted post-score calculated using group mean pre-score.

### Table 8. Transport Engineering Scale Scores by Statistically Significant Demographic Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-EiE Mean</th>
<th>Predicted Post-Score</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>White/Asian, Not FRL</td>
<td>1.212</td>
<td>3.301</td>
<td>3.043-3.559</td>
</tr>
<tr>
<td>White/Asian, FRL</td>
<td>1.229</td>
<td>2.774</td>
<td>2.264-3.284</td>
</tr>
<tr>
<td>Black/Hispanic, Not FRL</td>
<td>1.000</td>
<td>2.561</td>
<td>2.037-3.085</td>
</tr>
<tr>
<td>Black/Hispanic, FRL</td>
<td>1.261</td>
<td>2.097</td>
<td>1.412-2.781</td>
</tr>
</tbody>
</table>

The model provides evidence that students’ scores on the Transport Engineering scale significantly improved from pre- to post-assessment (p<.001). Once again, higher pre-test scores are significantly associated with improved predicted scores (p<.001). As with the Design scale, students receiving FRL and those who are Black or Hispanic do not improve as much as White/Asian students not receiving FRL, but all demographics feature confidence intervals.
above the group pre-test mean. This means we can still be confident in predicting that these students’ scores improved significantly.

**Designing Maglev Systems: Properties of Magnets Scale**

A scale with a high score of 13, the Properties of Magnets scale measures student performance on questions about the scientific properties of magnets and magnetic materials, as well as interactions between magnets and their poles. A significant model emerged from backwards step-wise regression: $F(2,356)=82.425$, $p<.001$. It explains 31.3% of the variance (Adj. $R^2=.313$) and has a 1.389 standard deviation of residuals. Information on the model can be found in Table 9 and changes in scores are shown in Table 10 and Figure 8.

**Table 9. Summary of Variables in Properties of Magnets Scale Model**

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE B</th>
<th>β</th>
<th>t-value</th>
<th>p-value</th>
<th>Cohen's $d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Reference Group)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not FRL</td>
<td>2.738</td>
<td>.137</td>
<td>19.951</td>
<td>&lt;.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre Prop. Mag.</td>
<td>.340</td>
<td>.039</td>
<td>.403</td>
<td>8.620</td>
<td>&lt;.001</td>
<td>0.245</td>
</tr>
<tr>
<td>FRL</td>
<td>-1.429</td>
<td>.241</td>
<td>-.277</td>
<td>-5.921</td>
<td>&lt;.001</td>
<td>-1.029</td>
</tr>
</tbody>
</table>

**Table 10. Properties of Magnets Scale Scores by Statistically Significant Demographics**

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-EiE Mean</th>
<th>Predicted Post-Score</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not FRL</td>
<td>8.096</td>
<td>10.554</td>
<td>9.838-11.270</td>
</tr>
<tr>
<td>FRL</td>
<td>5.611</td>
<td>8.280</td>
<td>7.417-9.143</td>
</tr>
</tbody>
</table>

*Bold denotes “reference group.” Predicted post-score calculated using group mean pre-score.*

**Figure 8. Predicted Post-score with 95% CI for Properties of Magnets Scale Model**

![Image of predicted post-score with 95% CI for Properties of Magnets Scale Model]
According to this model, students’ scores on the Properties of Magnets scale significantly improved from pre- to post-assessment (p<.001). The pre-tests once again had a significant impact (p<.001). Although students receiving FRL had significantly lower scores on both the pre- and post-assessments than the reference group, the 95% confidence interval is still well above the group’s pre-mean, so predicted change was still positive. Unlike the other scales in *Designing Maglev Systems*, Black and Hispanic students did not perform significantly differently on the Properties of Magnets scale from the reference group.

**Summary: “Designing Maglev Systems” Evaluation**

Our analysis suggests that students participating in EiE’s *Designing Maglev Systems* and an associated science unit are learning about engineering and science related to magnets and maglev transportation systems. Students significantly improved in their performance from pre- to post-assessment on scales of engineering-oriented questions about designing maglev systems and the nature of transportation engineering. They also significantly improved on the science-oriented scale of questions about the properties of magnets. Students receiving free or reduced-price lunch improved on all three scales, but had lower scores than the reference group. Similarly, the performance of racially underrepresented (Black, Hispanic, and Other) students was frequently less than that of Whites and Asians on the two engineering scales only, although underrepresented students also improved.

**Results for the “Designing Water Filters” Unit Evaluation**

In the EiE unit *Water, Water Everywhere: Designing Water Filters*, students are introduced to environmental engineering through the story of Salila, a girl in India, who designs a water filtration system for a turtle she rescues (Lesson 1). Students learn about the prevention of water contamination (Lesson 2) and test different filter materials for their ability to remove contaminants from water (Lesson 3). In the design challenge (Lesson 4), students use the engineering design process to design, test, and improve their own water filters.

**Assessment Design: “Designing Water Filters”**

The *Designing Water Filters* assessment was first designed in 2004 to assess the original version of the *Designing Water Filters* unit. In preparation for testing in Minnesota during the 2010-2011 school year, the assessment was revised in summer of 2010. The assessment consists of 25 questions about the water cycle, water pollution, and environmental engineering. Students completed identical pre- and post-assessments. The text of questions and answers can be found in Figure 22 of Appendix B.
Scale Construction: “Designing Maglev Systems”

The scales for *Designing Water Filters* were constructed from factor analyses performed during revision of the assessment. For the Minnesota 2010-2011 school year sample, scales were tested for reliability on students’ post-assessments. Information about this testing can be found in Table 11. Bold titles of scales indicate those analyzed and discussed in the results section.

### Table 11. Summary of Scales and Reliability: Designing Water Filters

<table>
<thead>
<tr>
<th>Scale</th>
<th># of Items</th>
<th>Questions</th>
<th>Content Assessed</th>
<th>N</th>
<th>Reliability (Cronbach’s α)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Items</td>
<td>25</td>
<td>1-25</td>
<td>All Questions</td>
<td>124</td>
<td>.740</td>
</tr>
<tr>
<td>Water Cycle</td>
<td>6</td>
<td>3, 8-11, 25</td>
<td>Science of the Water Cycle</td>
<td>152</td>
<td>.486</td>
</tr>
<tr>
<td>Pollution</td>
<td>6</td>
<td>7, 13, 16-19</td>
<td>Contamination of Water</td>
<td>149</td>
<td>.638</td>
</tr>
<tr>
<td>Environmental Engineering</td>
<td>13</td>
<td>1, 2, 4-6, 12,</td>
<td>Nature of environmental</td>
<td>142</td>
<td>.481</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14, 15, 20-24</td>
<td>engineering work</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Bold indicates scales reported in results*

**Sample: “Designing Water Filters”**

The full *Designing Water Filters* sample consisted of 243 students in 9 fourth grade classrooms. Ultimately, 32.5% of the sample was dropped (n=79) due to missing or incomplete (fewer than 19 of 25 questions answered) pre- or post-assessments or missing demographic information. The final sample used for analysis retained data from 164 students.

A breakdown of the demographics for the sample is provided in Table 38 in Appendix A. Slightly over half of the sample was female. Other demographics, however, were slightly different for the *Designing Water Filters* sample as compared to other units. Over 80% of the sample receives free or reduced-price lunch (FRL), and about one fifth are categorized as ELL or have an IEP. Although ELL and IEP variables here represent over 10% of the sample, we chose not to include them in the analysis for consistency with results from other units. Using the same bin categories for these analyses as in the other units, racially underrepresented (Black, Hispanic, and Other) students actually make up 72.5% (n=119) of the sample, while “represented” (White and Asian) students make up the other 27.5% (n=45).

**Results: “Designing Water Filters”**

The lack of a control group prevents us from claiming that EiE is the cause of student learning, and the small sample size (less than 200 students) dramatically reduces the power of the analysis to detect improvement in student scores. Nevertheless, the analysis of *Designing Water Filters* still allows us to assess whether EiE students did grossly better on post-assessments compared to pre-assessments for scales of questions and to examine the possible effects of demographic variables on this change. Bolded scales on Table 11 in Appendix A were calculated as the sum of correct answers on the scale’s questions. Using backwards step-wise regression, we analyzed the effects of the covariate pre-assessment score and the independent demographic variables, bolded in Table 38, on the post-assessment scale scores.
**Designing Water Filters: Water Cycle Scale**

The Water Cycle scale measured student performance on questions about the science of the water cycle and state changes in water. The scale had a highest possible score of 6. Backwards step-wise regression revealed a significant model: $F(2, 161)=13.467, p<.001$. The model explains only 13.3% of the variance (Adj. $R^2=.133$), indicating a very small sample size and/or insufficient specification of important variables. It has a standard deviation of the residuals of 0.563. Relevant statistics, including regression coefficients, can be found below in Table 12. Changes in score for demographic variables are depicted in Table 13 and Figure 9.

Table 12. Summary of Variables in Water Cycle Scale Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE B</th>
<th>β</th>
<th>t-value</th>
<th>p-value</th>
<th>Cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>White/Asian (Reference Group)</td>
<td>2.397</td>
<td>.285</td>
<td>8.398</td>
<td>&lt;.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre Water Cycle</td>
<td>.312</td>
<td>.078</td>
<td>.303</td>
<td>3.989</td>
<td>&lt;.001</td>
<td>0.554</td>
</tr>
<tr>
<td>Black/Hispanic</td>
<td>-.496</td>
<td>.241</td>
<td>-.156</td>
<td>-2.057</td>
<td>.041</td>
<td>-0.881</td>
</tr>
</tbody>
</table>

Table 13. Water Cycle Scale Scores by Statistically Significant Demographic Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-EiE Mean</th>
<th>Predicted Post-Score</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>White/Asian</td>
<td>2.571</td>
<td>3.199</td>
<td>2.630-3.769</td>
</tr>
<tr>
<td>Black/Hispanic</td>
<td>1.969</td>
<td>2.515</td>
<td>1.769-3.262</td>
</tr>
</tbody>
</table>

Bold denotes “reference group.” Predicted post-score calculated using group mean pre-score.

Figure 9. Predicted Post-score with 95% CI for Water Cycle Scale Model
The model shows evidence that student scores on the Water Cycle scale significantly increased from pre- to post-assessment (p<.001). Pre-assessment scores had a significant positive effect on post-test scores (p<.001). Students in underrepresented racial demographics improved significantly less than those in the reference group. The confidence intervals for both groups, however, include the group’s pre-mean, an effect that is probably due to the smaller sample sizes once the data set is segmented into demographic groups. This means that we cannot confidently predict that students in either of these groups actually improved on the Water Cycle scale.

**Designing Water Filters: Pollution Scale**

The Pollution scale features questions about sources and effects of water contamination, measured on a scale of 0-6. The model derived by regression was significant ($F(2, 161)=35.480$, p<.001) and explains 29.7% of the variance (Adj. R²=.297) with a .961 standard deviation of the residuals. Table 14 presents relevant statistics from the model, and demographics with significant effects are shown in Table 15 and Figure 10.

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE B</th>
<th>β</th>
<th>t-value</th>
<th>p-value</th>
<th>Cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Reference Group) White/Asian</td>
<td>2.070</td>
<td>.279</td>
<td></td>
<td>7.408</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td>Pre Pollution</td>
<td>.537</td>
<td>.073</td>
<td>.493</td>
<td>7.381</td>
<td>&lt;.001</td>
<td>0.559</td>
</tr>
<tr>
<td>Black/Hispanic</td>
<td>-.656</td>
<td>.247</td>
<td>-.177</td>
<td>-2.653</td>
<td>.009</td>
<td>-0.683</td>
</tr>
</tbody>
</table>

Table 14. Summary of Variables in Pollution Scale Model

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-EiE Mean</th>
<th>Predicted Post-Score</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>White/Asian</td>
<td>2.571</td>
<td>3.451</td>
<td>2.892-4.009</td>
</tr>
<tr>
<td>Black/Hispanic</td>
<td>2.016</td>
<td>2.496</td>
<td>1.751-3.242</td>
</tr>
</tbody>
</table>

Bold denotes “reference group.” Predicted post-score calculated using group mean pre-score.

The model suggests that students’ scores on the Pollution scale significantly improved from pre-to post-assessment (p<.001). Higher pre-test scores once again predict a more significant improvement (p<.001). As in the Water Cycle scale, students from racially underrepresented groups did not improve as much as the reference group and have a confidence interval that includes the group pre-mean. Thus, we cannot determine whether these students’ scores improved. White and Asian student scores, however, can be seen to have improved significantly beyond the group pre-mean.
Designing Water Filters: Environmental Engineering Scale

The final scale of *Designing Water Filters* is the Environmental Engineering scale. With a high score of 11, the scale contains questions about the work that environmental engineers do and about the engineering of the water filter that students create during the unit’s design challenge. Through backwards step-wise regression, a significant model emerged ($F(2,160)=7.799$, $p=.001$) explaining only 7.7% of the variance (Adj. $R^2=.077$)—such a low amount of variance explained indicates either that the sample size was too small for the model to have sufficient power, and/or that important variables have not been specified. This model has a .643 standard deviation of residuals. Relevant statistics can be found on Table 16 with a summary in Table 17 and Figure 11.

### Table 16. Summary of Variables in Environmental Engineering Scale Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE B</th>
<th>β</th>
<th>t-value</th>
<th>p-value</th>
<th>Cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Reference Group) White/Asian</td>
<td>6.955</td>
<td>.571</td>
<td>12.186</td>
<td>&lt;.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black/Hispanic</td>
<td>-1.014</td>
<td>.360</td>
<td>-2.817</td>
<td>.005</td>
<td>-1.577</td>
<td></td>
</tr>
</tbody>
</table>

### Table 17. Environmental Eng. Scale Scores by Statistically Significant Demographic Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-EiE Mean</th>
<th>Predicted Post-Score</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black/Hispanic</td>
<td>4.813</td>
<td>6.730</td>
<td>5.380-8.080</td>
</tr>
</tbody>
</table>

*Bold denotes “reference group.” Predicted post-score calculated using group mean pre-score.*
Despite the low variance explained, the model predicts that students’ scores on the Environmental Engineering scale significantly improved from pre- to post-assessment (p<.001). Unlike every other scale for the unit-specific analyses, pre-test scores did not have a significant effect. As with the other Designing Water Filters scales, Black and Hispanic students had lower scores, on average, than the reference group. However, the confidence interval for these scores did not include the group pre-means, so we can confidently predict that both the White/Asian and Black/Hispanic student groups’ scores increased.

**Summary: “Designing Water Filters” Evaluation**

Our analysis of the Designing Water Filters unit suggests that students participating in this unit learn about environmental science and engineering. In general, students significantly improved their scores from pre- to post-assessment on scales related to the science of the water cycle and water contamination and on a scale regarding environmental engineering work and design of water filters. For both the Water Cycle scale and the Pollution scale, it is possible that students from underrepresented racial groups do not actually improve, as compared to the reference group. On questions about environmental engineering and the design challenge, however, these students do improve, despite their mean scores being lower than those of the reference group. The small sample size for this analysis, however, suggests extra caution in interpreting the results, as it leads to reduced power to find significant differences.
Results for the “Designing Model Membranes” Unit Evaluation

In the EiE unit *Just Passing Through: Designing Model Membranes*, students are introduced to bioengineering through a story in which a boy from El Salvador, Juan Daniel, uses bioengineering to create an artificial membrane to keep a pet frog’s skin moist and save its life (Lesson 1). Students learn more about technologies that have similar functions to natural objects (Lesson 2), explore the properties of natural membranes, and test the performance of different model membrane materials (Lesson 3). In the design challenge (Lesson 4), students use the engineering design process to create, test, and improve their own model membranes.

Assessment Design: “Designing Model Membranes”

The *Designing Model Membranes* assessment was revised in spring of 2009 and used for testing in Minnesota during the 2009-2010 school year. It was shortened in summer of 2010 in preparation for testing in the 2010-2011 school year in Minnesota.

Students answered 27 multiple-choice questions on identical pre- and post-assessments about the science of survival needs and adaptations and the design of membranes. The assessment is presented in Figure 23 of Appendix B.

Scale Construction: “Designing Model Membranes”

*Designing Model Membranes* scales were constructed during testing of the data from Minnesota’s 2009-2010 school year. During the summer, items detracting from inter-item correlation on these scales were dropped in order to make the assessment shorter. The revised scales are displayed in Table 21, with Cronbach’s alpha reported for post-assessments.

Table 18. Summary of Scales and Reliability Results: Model Membranes

<table>
<thead>
<tr>
<th>Scale</th>
<th># of Items</th>
<th>Questions</th>
<th>Content Assessed</th>
<th>N</th>
<th>Reliability (Cronbach’s α)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Items</td>
<td>27</td>
<td>1-27</td>
<td>All Questions</td>
<td>330</td>
<td>.830</td>
</tr>
<tr>
<td>Bioengineering</td>
<td>5</td>
<td>3, 8, 11, 16, 25</td>
<td>Nature of bioengineering work</td>
<td>384</td>
<td>.693</td>
</tr>
<tr>
<td>Survival Needs and Adaptation</td>
<td>6</td>
<td>5, 7, 9, 10, 14, 18</td>
<td>Science of biological adaptations</td>
<td>380</td>
<td>.589</td>
</tr>
<tr>
<td>Designs from Nature</td>
<td>7</td>
<td>13, 17, 19-23</td>
<td>Engineering inspired by nature</td>
<td>377</td>
<td>.640</td>
</tr>
<tr>
<td>Membranes</td>
<td>10</td>
<td>1, 2, 4, 6, 12, 15, 22, 24, 26, 27</td>
<td>Natural and man-made membranes</td>
<td>355</td>
<td>.604</td>
</tr>
<tr>
<td>Membranes in Nature</td>
<td>7</td>
<td>1, 2, 4, 6, 22, 26, 27</td>
<td>Examples of natural membranes</td>
<td>363</td>
<td>.527</td>
</tr>
<tr>
<td>Human-made Membranes</td>
<td>6</td>
<td>12, 15, 22, 24, 26, 27</td>
<td>Design of model membranes</td>
<td>359</td>
<td>.506</td>
</tr>
</tbody>
</table>

*Bold indicates scales reported in results*
Sample: “Designing Model Membranes”

The Designing Model Membranes full sample consisted of 607 students in 21 third grade classrooms. Missing or incomplete (fewer than 21 of 27 questions answered) pre- or post-assessments or demographic information prompted us to drop 34.3% (n=208) of the sample, creating a final sample for analysis consisting of 399 students.

Demographics for the Designing Model Membranes sample are provided in Table 39 in Appendix A. Slightly under half of the sample is male, and just over a quarter receives free or reduced-price lunch (FRL) from the National School Lunch Program. As in the other samples, students with IEPs make up less than 10% of the sample. Although ELL students comprise 12% of the sample, neither IEP nor ELL variables were used in order to maintain consistent analysis across units. Racial demographics were also consolidated in the same way. Represented (White and Asian) students made up 68.5% of the sample (n=273), while Underrepresented (Black, Hispanic, and Other) students made up 31.5% (n=126). Students taught by a teacher who had SMM resident training in the prior year made up 83.0% (n=331) of the sample.

Results: “Designing Model Membranes”

Like all other groups, the Designing Model Membranes analysis lacked a control group; thus, analyzing the assessment can only tell us whether EiE students significantly improved in performance from pre- to post-test and whether demographic variables had an effect. The scales in were calculated as the sum of correct answers to scale questions, then analyzed with backwards step-wise regression.

Designing Model Membranes: Bioengineering Scale

The Bioengineering scale measures student performance on questions about the nature of work in the bioengineering field, with a possible high score of 5. Backwards step-wise regression revealed a significant model: $F(3,391)=40.311, p<.001$, explaining 23.0% of the variance (Adj. $R^2=.230$). The standard deviation of residuals was 0.756. Regression coefficients and relevant statistics for predictor variables from this model can be found in Table 19. The group pre-means and scores predicted by the model are also depicted in Table 20 and Figure 12.

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE B</th>
<th>β</th>
<th>t-value</th>
<th>p-value</th>
<th>Cohen's d</th>
</tr>
</thead>
<tbody>
<tr>
<td>White/Asian, not FRL</td>
<td>3.261</td>
<td>.119</td>
<td></td>
<td>27.291</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td>Pre Bioeng.</td>
<td>.237</td>
<td>.058</td>
<td>.184</td>
<td>4.077</td>
<td>&lt;.001</td>
<td>0.314</td>
</tr>
<tr>
<td>FRL</td>
<td>-1.047</td>
<td>.188</td>
<td>-.326</td>
<td>-5.565</td>
<td>&lt;.001</td>
<td>-1.385</td>
</tr>
<tr>
<td>Black/Hispanic</td>
<td>-.405</td>
<td>.196</td>
<td>-.121</td>
<td>-2.070</td>
<td>.039</td>
<td>-0.536</td>
</tr>
</tbody>
</table>
Table 20. Bioengineering Scale Scores by Statistically Significant Demographic Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-EiE Mean</th>
<th>Predicted Post-Score</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>White/Asian, Not FRL</td>
<td>1.325</td>
<td>3.575</td>
<td>3.337-3.813</td>
</tr>
<tr>
<td>Black/Hispanic, Not FRL</td>
<td>0.800</td>
<td>2.404</td>
<td>1.959-2.849</td>
</tr>
<tr>
<td>White/Asian, FRL</td>
<td>1.000</td>
<td>3.093</td>
<td>2.634-3.552</td>
</tr>
<tr>
<td>Black/Hispanic, FRL</td>
<td>0.856</td>
<td>2.012</td>
<td>1.419-2.605</td>
</tr>
</tbody>
</table>

Bold denotes “reference group.” Predicted post-score calculated using group mean pre-score.

Figure 12. Predicted Post-score with 95% CI for Bioengineering Model

According to the model, student scores on the Bioengineering scale significantly increased from pre- to post-assessment (p<.001). As in other scales, pre-assessment scores had a significant positive effect on post-test scores (p<.001). Scores from underrepresented students and those receiving FRL were lower than those of White/Asian students not receiving FRL, but confidence intervals are well above pre-means, suggesting that scores in these groups increased significantly from pre-to post-test.

Designing Model Membranes: Survival Needs and Adaptations (SNA) Scale

The Survival Needs and Adaptations (SNA) scale consists of science questions about examples of biological adaptations for particular survival needs; it has a high score of 6. A significant model ($F(3,395)=81.362$, p<.001) was derived from backwards step-wise regression that explains 37.7% of the variance (Adj. R²=.377) with a .966 standard deviation of the residuals. Relevant statistics (Table 21) and a summary of effects on group scores (Table 22 and Figure 13) are presented below.
Table 21. Summary of Variables in SNA Scale Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE</th>
<th>β</th>
<th>t-value</th>
<th>p-value</th>
<th>Cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Reference Group)</td>
<td>Not FRL, Workshop-Trained</td>
<td>1.943</td>
<td>.252</td>
<td>7.697</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td>Pre SNA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FRL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-Residency</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 22. SNA Scale Scores by Statistically Significant Demographic Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-EiE Mean Score</th>
<th>Predicted Post-Score</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not FRL, Workshop-Trained</td>
<td>4.410</td>
<td>4.250</td>
<td>3.746-4.754</td>
</tr>
<tr>
<td>FRL, Workshop-Trained</td>
<td>3.033</td>
<td>3.024</td>
<td>2.444-3.605</td>
</tr>
<tr>
<td>Not FRL, Post-Residency</td>
<td>4.267</td>
<td>4.589</td>
<td>3.977-5.180</td>
</tr>
<tr>
<td>FRL, Post-Residency</td>
<td>2.648</td>
<td>3.227</td>
<td>2.560-3.894</td>
</tr>
</tbody>
</table>

Bold denotes “reference group.” Predicted post-score calculated using group mean pre-score.

Figure 13. Predicted Post-score with 95% CI for SNA Scale Model

The model for the Survival Needs and Adaptations scale suggests significant improvement (p<.001). Pre-test scores had a significant positive effect on post-tests predicted scores (p<.001). The FRL demographic variable showed a significant negative effect on scores, although neither the FRL nor non-FRL student groups had a confidence interval beyond the pre-mean, so we cannot confidently predict that these scores improved. The Residency variable showed a similarly minimal effect, with a confidence interval overlapping the group pre-means, but it is clear that in both cases the predicted post-scores were higher than the pre-means, albeit insignificantly higher. The lack of significant findings in subsamples may be due to small sample sizes in the subsamples.
Engineering is Elementary

**Designing Model Membranes: Designs from Nature Scale**

With a high score of 7, the Designs from Nature scale features questions about inspirations for engineering derived from natural systems, particularly biological membranes. Through analysis, a significant backwards step-wise regression model emerged: $F(3,395)=81.985, p<.001$. The model explains 37.9% of the variance (Adj. $R^2=.379$) with a 1.050 standard deviation of the residuals. Below, the model is presented in Table 23, Table 24, and Figure 14.

**Table 23. Summary of Variables in Designs from Nature Scale Model**

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE B</th>
<th>β</th>
<th>t-value</th>
<th>p-value</th>
<th>Cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Reference Group)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White/Asian, not FRL</td>
<td>3.913</td>
<td>.208</td>
<td></td>
<td>18.774</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td>Pre Designs From Nature</td>
<td>.442</td>
<td>.043</td>
<td>.429</td>
<td>10.275</td>
<td>&lt;.001</td>
<td>0.421</td>
</tr>
<tr>
<td>FRL</td>
<td>-.643</td>
<td>.184</td>
<td>-.184</td>
<td>-3.500</td>
<td>.001</td>
<td>-0.613</td>
</tr>
<tr>
<td>Black/Hispanic</td>
<td>-.645</td>
<td>.192</td>
<td>-.177</td>
<td>-3.357</td>
<td>.001</td>
<td>-0.614</td>
</tr>
</tbody>
</table>

**Table 24. Designs from Nature Scale Scores by Statistically Significant Demographic Groups**

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-EiE Mean</th>
<th>Predicted Post-Score</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>White/Asian, Not FRL</td>
<td>4.513</td>
<td>5.908</td>
<td>5.492-6.324</td>
</tr>
<tr>
<td>Black/Hispanic, Not FRL</td>
<td>3.556</td>
<td>4.840</td>
<td>4.218-5.328</td>
</tr>
<tr>
<td>White/Asian, FRL</td>
<td>3.400</td>
<td>4.773</td>
<td>4.273-5.406</td>
</tr>
<tr>
<td>Black/Hispanic, FRL</td>
<td>3.189</td>
<td>4.034</td>
<td>3.359-4.710</td>
</tr>
</tbody>
</table>

Bold denotes "reference group." Predicted post-score calculated using group mean pre-score.

The model shows students’ scores on the Design from Nature scale significantly improving from pre- to post-assessment ($p<.001$). Pre-tests had a significant positive impact on post-test scores ($p<.001$). Students receiving FRL or who are from underrepresented racial groups have significantly lower scores than White/Asian students not on FRL, but in both cases have confidence intervals above the group pre-test means, suggesting they still improved significantly. Students falling under both of these categories may not improve significantly, as the confidence interval for post-test scores does cover the pre-test mean, but the effect for these students may be exaggerated due to high correlation between the Black/Hispanic and FRL variables (Pearson’s R=.653).
Designing Model Membranes: Membranes Scale

The Membranes scale measured student performance on questions about membranes, both naturally occurring membranes and man-made membranes, including those that students make in the unit’s design challenge. The scale had a high score of 10. A significant model \( F(3,389)=51.812, p<.001 \) through backwards step-wise regression that explains 28.0% of the variance (Adj. R²=.280). The standard deviation of residuals was 1.117. The model and effect sizes for variables can be found in Table 25, while pre-means and scores predicted by the model are shown in Table 26 and Figure 15.

According to the model, student Membrane scale scores significantly increased from pre- to post-test \( (p<.001) \). Pre-assessment scores had a significant positive effect on the outcome \( (p<.001) \). The Black/Hispanic and FRL variables once again had significant effects on predicted post-scores for students, but in all cases, improvement over the group pre-mean is significant.

Table 25. Summary of Variables in Membranes Scale Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE B</th>
<th>( \beta )</th>
<th>t-value</th>
<th>p-value</th>
<th>Cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Reference Group)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White/Asian, Not FRL</td>
<td>6.451</td>
<td>.240</td>
<td>-</td>
<td>26.930</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td>Pre Membranes</td>
<td>.284</td>
<td>.046</td>
<td>.280</td>
<td>6.221</td>
<td>&lt;.001</td>
<td>0.025</td>
</tr>
<tr>
<td>FRL</td>
<td>-1.237</td>
<td>.251</td>
<td>-.286</td>
<td>-4.921</td>
<td>&lt;.001</td>
<td>-1.107</td>
</tr>
<tr>
<td>Black/Hispanic</td>
<td>-.551</td>
<td>.257</td>
<td>-.122</td>
<td>-2.148</td>
<td>.032</td>
<td>-0.493</td>
</tr>
</tbody>
</table>
Table 26. Membranes Scale Scores by Statistically Significant Demographic Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-EiE Mean</th>
<th>Predicted Post-Score</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>White/Asian, Not FRL</td>
<td>4.692</td>
<td>7.784</td>
<td>7.304-8.264</td>
</tr>
<tr>
<td>Black/Hispanic, Not FRL</td>
<td>4.250</td>
<td>7.107</td>
<td>5.381-6.770</td>
</tr>
<tr>
<td>White/Asian, FRL</td>
<td>3.035</td>
<td>6.076</td>
<td>6.404-7.810</td>
</tr>
<tr>
<td>Black/Hispanic, FRL</td>
<td>3.226</td>
<td>5.579</td>
<td>4.715-6.443</td>
</tr>
</tbody>
</table>

Bold denotes “reference group.” Predicted post-score calculated using group mean pre-score.

Figure 15. Predicted Post-score with 95% CI for Membranes Model

Summary: “Designing Model Membranes” Evaluation

Our analysis of the student data from Designing Model Membranes suggests that students experiencing this engineering unit paired with an appropriate science unit learn about the science and bioengineering related to membranes. On scales of questions about the nature of bioengineering work and inspiration for technologies derived from natural adaptations, student performance improved from pre- to post-assessment. Underrepresented racial and ethnic minorities and students receiving free or reduced-price lunch from the National School Lunch Program improved slightly less than other students, with students in both categories possibly not improving on bioengineering questions. Similar demographic effects were observed for science questions about natural and man-made membranes, with all students still improving. While we cannot confidently predict it due to variance in the data, students whose teachers were trained by SMM residents appear to have performed slightly better on science questions about survival needs and adaptations than students with teachers trained in workshops.
Results for the “Seeing Animal Sounds” Unit Evaluation

In the EiE unit *Sounds Like Fun: Seeing Animal Sounds*, students are introduced to the field of acoustical engineering through the story of Kwame, a blind child in Ghana who is preparing for a drumming festival (Lesson 1). Students investigate different ways to damp, or quiet, sound (Lesson 2) and then explore the role that acoustical engineers play in designing ways to visualize sound (Lesson 3). In the design challenge (Lesson 4), students learn about and use the engineering design process as they design, draw, and test a system for representing bird calls.

Assessment Design: “Seeing Animal Sounds”

The *Seeing Animal Sounds* assessment was originally designed in 2005, revised in spring of 2009, and used for testing in Minnesota during the 2009-2010 school year. It was shortened in summer of 2010 in preparation for testing in the 2010-2011 school year in Minnesota.

Students answered 27 multiple-choice questions on identical pre- and post-assessments about acoustical engineering, the properties of sound, how to change sound, and how to represent sound. The questions are presented in Figure 24 of Appendix B.

Scale Construction: “Seeing Animal Sounds”

*Seeing Animal Sounds* scales were constructed during testing of the data from Minnesota’s 2009-2010 school year. During revision, items that were detracting from inter-item correlation on these scales were dropped. These revised scales were used for analysis of the 2010-2011 data. Information about the scales, including reliability measures for the post-assessments, can be found in Table 27.

<table>
<thead>
<tr>
<th>Scale</th>
<th># of Items</th>
<th>Questions</th>
<th>Content Assessed</th>
<th>N</th>
<th>Reliability (Cronbach’s α)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Items</td>
<td>27</td>
<td>1-27</td>
<td>All Questions</td>
<td>147</td>
<td>.850</td>
</tr>
<tr>
<td>Properties of Sound</td>
<td>7</td>
<td>2, 4, 11, 13, 14, 18, 22</td>
<td>Scientific properties of sound</td>
<td>168</td>
<td>.670</td>
</tr>
<tr>
<td>Changing Sound</td>
<td>9</td>
<td>4, 5, 12, 15, 16, 17, 19, 20, 21</td>
<td>Manipulating pitch, volume, and duration</td>
<td>171</td>
<td>.682</td>
</tr>
<tr>
<td>Representing Sound</td>
<td>9</td>
<td>7, 8, 9, 10, 23, 24, 25, 26, 27</td>
<td>Depicting sound graphically</td>
<td>165</td>
<td>.690</td>
</tr>
</tbody>
</table>

Bold indicates scales reported in results

Sample: “Seeing Animal Sounds”

Data for *Seeing Animal Sounds* were collected from 250 students in 11 third grade classrooms. Due to students missing a pre- or post-assessment or demographic information, or filling out fewer than 21 of the 27 questions for either the pre- or post-assessment, 26.8% (n=67) of the sample was dropped, creating a final sample used for analysis consisting of 183 students’ data.
Demographics for the *Seeing Animal Sounds* sample are provided in Table 40 of Appendix A. Just over half of the sample was female. Slightly over a quarter receives FRL. As in the other samples, ELL’s and students with IEP’s made up less than 10% of the sample in each case and so these factors were excluded from analysis. Racial demographics were also consolidated in the same way. White and Asian students made up 73.2% of the sample (n=134), while underrepresented racial minority students (Black, Hispanic, or Other—e.g. Native American) made up 26.8% (n=49). For this unit, 47.0% students (n=86) were taught by teachers who were trained by SMM residents; the rest were taught by teachers who received training through a one-day workshop.

**Results: “Seeing Animal Sounds”**

The *Seeing Animal Sounds* sample lacks a control group, thus the results of the assessment can tell us only whether EiE students did significantly better on post-test scales compared to pre-tests, as well as the effects of demographic variables on this improvement. Bolded scales from Table 27 were calculated as the sum of correct answers to scale questions. The same type of backwards step-wise regression was performed on the scales and demographic variables as in other units.

*Seeing Animal Sounds: Properties of Sound Scale*

The Properties of Sound scale measured student performance on questions about the nature of pitch, volume, and duration in sound, with a possible high score of 7. Backwards step-wise regression revealed a significant model: $F(2,179)=21.316, p<.001$, explaining 18.3% of the variance (Adj. $R^2=.183$). The standard deviation of residuals was 0.741. Regression coefficients and relevant statistics for predictor variables from this model can be found in Table 28. The change in score predicted by the model is also depicted in Table 29 and Figure 16.

**Table 28. Summary of Variables in Properties of Sound Scale Model**

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE B</th>
<th>β</th>
<th>t-value</th>
<th>p-value</th>
<th>Cohen’s $d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Reference Group) White/Asian, Workshop-Trained</td>
<td>3.813</td>
<td>.304</td>
<td>12.540</td>
<td>&lt;.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre Prop Sound</td>
<td>.337</td>
<td>.069</td>
<td>.335</td>
<td>4.905</td>
<td>&lt;.001</td>
<td>0.431</td>
</tr>
<tr>
<td>Black/Hispanic</td>
<td>-.723</td>
<td>.269</td>
<td>-.186</td>
<td>-2.684</td>
<td>.008</td>
<td>-0.925</td>
</tr>
<tr>
<td>Residency</td>
<td>.506</td>
<td>.229</td>
<td>.150</td>
<td>2.211</td>
<td>.028</td>
<td>0.647</td>
</tr>
</tbody>
</table>

**Table 29. Properties of Sound Scale Scores by Statistically Significant Demographic Groups**

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-EiE Mean</th>
<th>Predicted Post-Score</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>White/Asian, Workshop-Trained</td>
<td>4.286</td>
<td>5.257</td>
<td>4.649-5.865</td>
</tr>
<tr>
<td>Black/Hispanic, Workshop-Trained</td>
<td>2.667</td>
<td>3.989</td>
<td>3.177-4.801</td>
</tr>
<tr>
<td>White/Asian, Residency-Trained</td>
<td>3.564</td>
<td>5.520</td>
<td>4.759-6.281</td>
</tr>
<tr>
<td>Black/Hispanic, Residency-Trained</td>
<td>2.786</td>
<td>4.535</td>
<td>3.603-5.467</td>
</tr>
</tbody>
</table>

**Bold** denotes “reference group.” Predicted post-score calculated using group mean pre-score.
The model shows evidence that student scores on the Properties of Sound scale significantly increased from pre- to post-assessment (p<.001). As has consistently been the case with other scales, higher pre-assessment scores had a significant positive effect on the outcome (p<.001). The scores of Black/Hispanic students were not as high as those of White/Asian students, but confidence intervals do not include the pre-test means, strong evidence that scores increased from pre- to post-test. Improvements for all racial groups, however, appear to be higher for those students with teachers who were trained by SMM residents, as evidenced by greater change in score from group pre-means to predicted post-means.

**Seeing Animal Sounds: Changing Sound Scale**

The Changing Sound scale consists of questions about ways to alter the pitch and volume of sound being made or perceived; it had a high score of 9. A significant model ($F(2,179)=41.510$, p<.001) was derived from backwards step-wise regression that explains 30.9% of the variance (Adj. $R^2=.309$) with a 1.188 standard deviation of the residuals. Relevant statistics (Table 30) and a summary of demographic group effects (Table 31 and Figure 17) are presented below.

### Table 30. Summary of Variables in Changing Sound Scale Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE B</th>
<th>$\beta$</th>
<th>t-value</th>
<th>p-value</th>
<th>Cohen’s $d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Reference Group) White/Asian</td>
<td>4.326</td>
<td>.381</td>
<td></td>
<td>11.348</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td>Pre Chang. Sound</td>
<td>.493</td>
<td>.072</td>
<td>.451</td>
<td>6.815</td>
<td>&lt;.001</td>
<td>0.415</td>
</tr>
<tr>
<td>Black/Hispanic</td>
<td>-1.016</td>
<td>.318</td>
<td>-.211</td>
<td>-3.192</td>
<td>.002</td>
<td>-0.855</td>
</tr>
</tbody>
</table>
Table 31. Changing Sound Scale Scores by Statistically Significant Demographic Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-EiE Mean</th>
<th>Predicted Post-Score</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>White/Asian</td>
<td>5.571</td>
<td>7.073</td>
<td>6.311-7.835</td>
</tr>
<tr>
<td>Black/Hispanic</td>
<td>5.000</td>
<td>5.775</td>
<td>4.782-6.768</td>
</tr>
</tbody>
</table>

Bold denotes “reference group.” Predicted post-score calculated using group mean pre-score.

Figure 17. Predicted Post-score with 95% CI for Changing Sound Scale Model

According to the model, students’ scores on the Changing Sound scale model significantly improved from pre- to post-assessment (p<.001). Higher pre-test scores significantly improved predicted scores (p<.001). As in the Properties of Sound scale, the demographic variable Black/Hispanic showed significant negative effects when compared to the reference group (White/Asian). In this case, the confidence interval for Black/Hispanic includes the group pre-mean, so we are not confident in predicting that scores of this group increased. Teacher residency did not have a significant effect on the Changing Sound scale scores.

Seeing Animal Sounds: Representing Sound Scale

With a high score of 9, the Representing Sound scale includes questions about designing and interpreting graphs depicting sound. A significant model emerged from backwards step-wise regression: $F(2177)=43.526$, p<.001. It explains 32.2% of the variance (Adj. R²=.322) with a 1.294 standard deviation of residuals. Relevant statistics for the model are found in Table 32 and pre- and post-scores are shown in Table 33 and Figure 18.
Table 32. Summary of Variables in Representing Sound Scale Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE B</th>
<th>β</th>
<th>t-value</th>
<th>p-value</th>
<th>Cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Reference Group)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not FRL</td>
<td>4.114</td>
<td>.358</td>
<td></td>
<td>11.495</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td>Pre Rep. Sound</td>
<td>.477</td>
<td>.069</td>
<td>.451</td>
<td>6.901</td>
<td>&lt;.001</td>
<td>0.369</td>
</tr>
<tr>
<td>FRL</td>
<td>-1.191</td>
<td>.332</td>
<td>-.234</td>
<td>-3.584</td>
<td>&lt;.001</td>
<td>-0.920</td>
</tr>
</tbody>
</table>

Table 33. Representing Sound Scale Scores by Statistically Significant Demographic Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-EI Mean</th>
<th>Predicted Post-Score</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not FRL</td>
<td>4.964</td>
<td>6.482</td>
<td>5.766-7.198</td>
</tr>
<tr>
<td>FRL</td>
<td>3.833</td>
<td>4.751</td>
<td>3.775-5.728</td>
</tr>
</tbody>
</table>

*Bold* denotes “reference group.” Predicted post-score calculated using group mean pre-score.

Figure 18. Predicted Post-score with 95% CI for Representing Sound Scale Model

The model provides evidence that students’ scores on the Representing Sound scale significantly improved from pre- to post-assessment (*p*<.001). The pre-tests yet again had a significant impact (*p*<.001). Unlike on the other scales from this unit, the Black/Hispanic variable did not have a significant effect. Students receiving FRL, though, had significantly lower scores than the reference group; the 95% confidence interval also includes the group pre-mean. This means that we cannot confidently predict that students receiving FRL improved their scores. Teacher residency did not have a significant effect on the Representing Sound scale.

Summary: “Seeing Animal Sounds” Evaluation

Analysis suggests that students experiencing the *Seeing Animal Sounds* unit, taught in conjunction with a related science unit, learn about the science and engineering of sound. On
scales of questions about engineering sound—both how to change properties of sound and how to visually represent sounds—and about the scientific properties of sound, students significantly improved in performance from pre- to post-assessment. Students receiving free or reduced-price lunch may or may not have improved from pre- to post-test on questions about graphically representing sound. The same is true for underrepresented racial minority students on questions about changing sound. Although underrepresented racial minority students scored lower on questions about the scientific properties of sound, they still improved. Teachers trained by SMM residents appear to have a greater effect on students’ science scores than their colleagues trained via the workshop.

Conclusions

Minneapolis and Hopkins students show significant improvement in attitudes toward, and understanding of, science and engineering after participating in EiE. Comparing pre-EiE and post-EiE surveys, students experience positive change in attitudes about (1) the work of scientists and engineers and (2) the relevance of science and math to the real world; and (3) also show a positive change in interest in future careers in science and engineering. These trends are evidenced by performing paired t-tests on student responses to the Engineering Attitudes survey before and after participation in EiE. The results of tests for those statements showing significance are presented in Table 1.

Students also improved on the post-assessments of unit-specific engineering and science content, as well as in their ideas about what constitutes technology—evidence that they acquired a more accurate and nuanced understanding of the nature of technology, as well as increased understanding of target science and engineering content.

Across all four EiE units, students improved significantly on metrics of learning about science and engineering. More specifically:

- Girls and boys evidenced the same amount of growth.
- Although underrepresented racial/ethnic minority students and students receiving free or reduced-price lunch (a measure of socio-economic status) tended to score lower on the test prior to engaging in EiE than other students, in most cases these students still showed significant growth in learning about science and engineering.
- As evidenced by student performance on assessments of science content, teachers trained by science specialists from the Science Museum of Minnesota appear to sometimes do better at integrating science and engineering content in their classrooms than teachers who did not have this advantage.

These trends are evidenced by performing linear regression on scales of students’ responses to pre- and post-assessments of science and engineering content. Pre-test responses were used as the covariate, with independent variables: Gender, Free or Reduced-Price Lunch status (FRL),...
Regression models for all scales indicated significant improvement.

Presented below in Table 34 is a summary of effect sizes for these regression models. Effect sizes should be interpreted as relative effects—a greater absolute value relative to the other effects in the model represents a greater effect of the variable on the significant regression model. The sign of the effect size indicates direction of the effect on student scores.

Table 34. Table of Variable Effect Sizes by Scale

<table>
<thead>
<tr>
<th>Unit/Scale Name</th>
<th>Pre-Test</th>
<th>Gender</th>
<th>FRL</th>
<th>Black/Hispanic</th>
<th>Residency</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is Technology?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Picture Grid</td>
<td>0.143</td>
<td>-</td>
<td>-</td>
<td>-1.782</td>
<td></td>
</tr>
<tr>
<td>Designing Maglev Systems</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design of Maglev Systems</td>
<td>0.367</td>
<td>-</td>
<td>-0.934</td>
<td>-0.697</td>
<td></td>
</tr>
<tr>
<td>Transportation Engineering</td>
<td>0.424</td>
<td>-</td>
<td>-0.882</td>
<td>-1.140</td>
<td></td>
</tr>
<tr>
<td>Properties of Magnets</td>
<td>0.245</td>
<td>-</td>
<td>-1.029</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Designing Water Filters</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Cycle</td>
<td>0.554</td>
<td>-</td>
<td>-</td>
<td>-0.881</td>
<td></td>
</tr>
<tr>
<td>Pollution</td>
<td>0.559</td>
<td>-</td>
<td>-</td>
<td>-0.683</td>
<td></td>
</tr>
<tr>
<td>Environmental Engineering</td>
<td>0.0255</td>
<td>-</td>
<td>-</td>
<td>-1.577</td>
<td></td>
</tr>
<tr>
<td>Designing Model Membranes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BioEngineering</td>
<td>0.314</td>
<td>-</td>
<td>-1.385</td>
<td>-0.536</td>
<td></td>
</tr>
<tr>
<td>Survival Needs and Adaptation</td>
<td>0.542</td>
<td>-</td>
<td>-0.523</td>
<td>-</td>
<td>0.418</td>
</tr>
<tr>
<td>Designs From Nature</td>
<td>0.421</td>
<td>-</td>
<td>-0.613</td>
<td>-0.614</td>
<td>-</td>
</tr>
<tr>
<td>Membranes</td>
<td>0.254</td>
<td>-</td>
<td>-1.107</td>
<td>-0.493</td>
<td>-</td>
</tr>
<tr>
<td>Seeing Animal Sounds</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Properties of Sound</td>
<td>0.431</td>
<td>-</td>
<td>-</td>
<td>-0.925</td>
<td>0.647</td>
</tr>
<tr>
<td>Changing Sound</td>
<td>0.415</td>
<td>-</td>
<td>-</td>
<td>-0.855</td>
<td>-</td>
</tr>
<tr>
<td>Representing Sound</td>
<td>0.369</td>
<td>-</td>
<td>-0.920</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Effect sizes calculated as Cohen’s d (variable’s model coefficient/SD of residuals).

It is not surprising that pre-test scores are a good predictor of post-test scores for students. Students are likely to slightly increase their scores from pre- to post-test as they are completing identical assessments, albeit many weeks apart.

As gender did not play a significant role in predicting scores for the general technology assessment or any of the unit-specific assessments, it appears that boys and girls experience similar gains while participating in EiE. Students from underrepresented racial minorities and those receiving free or reduced-price lunch do seem to improve, but not as significantly as White/Asian students and students not receiving free or reduced-price lunch. Particularly in cases where both of these demographic variables surfaced as significant, the Black/Hispanic and FRL variables demonstrate high co-linearity—that is, many students are both underrepresented minorities and also receive free or reduced-price lunch.

For the third grade units, the method of teacher training emerged as a significant factor for some science scales. Students taught by a teacher trained with SMM residents performed better
on some scales assessing understanding of the related science topic than students taught by teachers who were trained with a one-day workshop. That this effect is significant for some science questions but not for engineering questions suggests that it is possible that the biggest benefit to teachers of the SMM residents, at least as evidenced by student performance, may be an improvement in their ability to integrate science and engineering in the context of a design challenge in EiE. Further exploration of this hypothesized effect must be conducted in future studies.

References


Appendix A

Table 35. *Engineering Attitudes* Sample Demographics

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Proportion</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (proportion of males)</td>
<td>47.8%</td>
<td>255</td>
</tr>
<tr>
<td>Free or Reduced-Price Lunch (FRL)</td>
<td>47.0%</td>
<td>251</td>
</tr>
<tr>
<td>English Language Limited Proficiency (ELLP)</td>
<td>14.0%</td>
<td>75</td>
</tr>
<tr>
<td>Individualized Education Program (IEP)</td>
<td>10.1%</td>
<td>54</td>
</tr>
<tr>
<td><strong>Race</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>52.6%</td>
<td>281</td>
</tr>
<tr>
<td>Asian</td>
<td>5.6%</td>
<td>30</td>
</tr>
<tr>
<td>Other</td>
<td>2.1%</td>
<td>11</td>
</tr>
<tr>
<td>Black</td>
<td>24.9%</td>
<td>133</td>
</tr>
<tr>
<td>Hispanic</td>
<td>14.8%</td>
<td>79</td>
</tr>
</tbody>
</table>

*Bold* indicates demographic categories used for analysis (category N greater than 10% of total sample)

Table 36. *What is Technology?* Sample Demographics

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Proportion</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (proportion of males)</td>
<td>47.0%</td>
<td>239</td>
</tr>
<tr>
<td>English Language Limited Proficiency (ELLP)</td>
<td>9.3%</td>
<td>47</td>
</tr>
<tr>
<td>Individualized Education Program (IEP)</td>
<td>13.0%</td>
<td>66</td>
</tr>
<tr>
<td><strong>Race</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Represented</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>53.0%</td>
<td>269</td>
</tr>
<tr>
<td>Asian</td>
<td>5.7%</td>
<td>29</td>
</tr>
<tr>
<td>Other</td>
<td>2.2%</td>
<td>11</td>
</tr>
<tr>
<td>Underrepresented</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>27.6%</td>
<td>140</td>
</tr>
<tr>
<td>Hispanic</td>
<td>11.6%</td>
<td>59</td>
</tr>
</tbody>
</table>

*Bold* indicates demographic categories used for analysis (category N greater than 10% of total sample)
### Table 37. Designing Maglev Systems Sample Demographics

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Proportion</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (proportion of males)</td>
<td>48.6%</td>
<td>175</td>
</tr>
<tr>
<td>Free or Reduced-Price Lunch (FRL)</td>
<td>35.3%</td>
<td>127</td>
</tr>
<tr>
<td>English Language Limited Proficiency (ELLP)</td>
<td>1.1%</td>
<td>39</td>
</tr>
<tr>
<td>Individualized Education Program (IEP)</td>
<td>7.5%</td>
<td>27</td>
</tr>
<tr>
<td><strong>Race</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Represented</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>61.9%</td>
<td>223</td>
</tr>
<tr>
<td>Asian</td>
<td>6.4%</td>
<td>23</td>
</tr>
<tr>
<td>Other</td>
<td>1.1%</td>
<td>4</td>
</tr>
<tr>
<td><strong>Underrepresented</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>19.4%</td>
<td>70</td>
</tr>
<tr>
<td>Hispanic</td>
<td>11.1%</td>
<td>40</td>
</tr>
</tbody>
</table>

*Bold* indicates demographic categories used for analysis (category N greater than 10% of total sample)

### Table 38. Designing Water Filters Sample Demographics

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Proportion</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (proportion of males)</td>
<td>45.7%</td>
<td>75</td>
</tr>
<tr>
<td>Free or Reduced-Price Lunch (FRL)</td>
<td>81.7%</td>
<td>134</td>
</tr>
<tr>
<td>English Language Limited Proficiency (ELLP)</td>
<td>20.1%</td>
<td>33</td>
</tr>
<tr>
<td>Individualized Education Program (IEP)</td>
<td>18.9%</td>
<td>31</td>
</tr>
<tr>
<td><strong>Race</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Represented</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>22.0%</td>
<td>36</td>
</tr>
<tr>
<td>Asian</td>
<td>5.5%</td>
<td>9</td>
</tr>
<tr>
<td>Other</td>
<td>4.9%</td>
<td>8</td>
</tr>
<tr>
<td><strong>Underrepresented</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>46.3%</td>
<td>76</td>
</tr>
<tr>
<td>Hispanic</td>
<td>21.3%</td>
<td>35</td>
</tr>
</tbody>
</table>

*Bold* indicates demographic categories used for analysis (category N greater than 10% of total sample)
### Table 39. Designing Model Membranes Sample Demographics

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Proportion</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (proportion of males)</td>
<td>47.1%</td>
<td>188</td>
</tr>
<tr>
<td>Free or Reduced-Price Lunch (FRL)</td>
<td>37.6%</td>
<td>150</td>
</tr>
<tr>
<td>English Language Limited Proficiency (ELLP)</td>
<td>12.0%</td>
<td>48</td>
</tr>
<tr>
<td>Individualized Education Program (IEP)</td>
<td>7.1%</td>
<td>28</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Race Represented</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>60.2%</td>
<td>240</td>
</tr>
<tr>
<td>Asian</td>
<td>8.3%</td>
<td>33</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Race Underrepresented</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Other</td>
<td>2.0%</td>
<td>8</td>
</tr>
<tr>
<td>Black</td>
<td>19.8%</td>
<td>79</td>
</tr>
<tr>
<td>Hispanic</td>
<td>9.8%</td>
<td>39</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Race Residency</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Residency</td>
<td>83.0%</td>
<td>331</td>
</tr>
</tbody>
</table>

*Bold* indicates demographic categories used for analysis (category N greater than 10% of total sample)

### Table 40. Seeing Animal Sounds Sample Demographics

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Proportion</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (proportion of males)</td>
<td>47.0%</td>
<td>86</td>
</tr>
<tr>
<td>Free or Reduced-Price Lunch (FRL)</td>
<td>26.2%</td>
<td>48</td>
</tr>
<tr>
<td>English Language Limited Proficiency (ELLP)</td>
<td>7.7%</td>
<td>14</td>
</tr>
<tr>
<td>Individualized Education Program (IEP)</td>
<td>8.7%</td>
<td>16</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Race Represented</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>65.0%</td>
<td>119</td>
</tr>
<tr>
<td>Asian</td>
<td>8.2%</td>
<td>15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Race Underrepresented</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Other</td>
<td>1.1%</td>
<td>2</td>
</tr>
<tr>
<td>Black</td>
<td>16.4%</td>
<td>30</td>
</tr>
<tr>
<td>Hispanic</td>
<td>9.3%</td>
<td>17</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Race Residency</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Residency</td>
<td>47.0%</td>
<td>86</td>
</tr>
</tbody>
</table>

*Bold* indicates demographic categories used for analysis (category N greater than 10% of total sample)
## Appendix B

### Figure 19. Engineering Attitudes Survey

We are interested in your opinions about science and engineering in this survey. Please answer each question honestly. Mark how strongly you agree or disagree after each statement. Thank you very much!

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat</th>
<th>Not Sure</th>
<th>Agree</th>
<th>Somewhat</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I would enjoy being a scientist when I grow up.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>2. I would enjoy being an engineer when I grow up.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>3. I would like a job where I could invent things.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>4. I would like to help plan bridges, skyscrapers, and tunnels.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>5. I would like a job that lets me design cars.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>6. I would like to build and test machines that could help people walk.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>7. I would enjoy a job helping to make new medicines.</td>
<td>○</td>
<td>○</td>
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</tr>
<tr>
<td>8. I would enjoy a job helping to protect the environment.</td>
<td>○</td>
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</tr>
<tr>
<td>9. Science has nothing to do with real life.</td>
<td>○</td>
<td>○</td>
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<td>○</td>
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<td>○</td>
</tr>
<tr>
<td>10. Math has nothing to do with real life.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
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<td>○</td>
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</tr>
<tr>
<td>11. I would like a job that lets me figure out how things work.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
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</tr>
<tr>
<td>12. I like thinking of new and better ways of doing things.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>13. I like knowing how things work.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>14. I am good at putting things together.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>15. Scientists cause problems in the world.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>16. Engineers cause problems in the world.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>17. Scientists help make people’s lives better.</td>
<td>○</td>
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<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>18. Engineers help make people’s lives better.</td>
<td>○</td>
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<td>○</td>
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<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>19. I think I know what scientists do for their jobs.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>20. I think I know what engineers do for their jobs.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>
Figure 20. *What is Technology?* Assessment Picture Grid

*Filled circles indicate correct answers*

<table>
<thead>
<tr>
<th>Wind-up Toy</th>
<th>Running Shoes</th>
<th>Sandals</th>
<th>Broom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MP3 Player</th>
<th>Volcano</th>
<th>Piano</th>
<th>Laptop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bird</th>
<th>Windmill</th>
<th>Keyboard</th>
<th>Bonnet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bicycle</th>
<th>Hand-held Fan</th>
<th>Roller Blades</th>
<th>Basket</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Oak Tree</th>
<th>Dandelion</th>
<th>Game Controller</th>
<th>Cell Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
For each question below, fill in the bubble for the **BEST** answer.

1. **The picture below shows Magnet 2 being pushed toward Magnet 1.**

   Which of the following will **MOST LIKELY** happen to Magnet 1 as Magnet 2 is moved closer?

   (a) Magnet 1 will not move.

   (b) Magnet 1 will move under Magnet 2.

   (c) Magnet 1 will move toward Magnet 2.

   (●) Magnet 1 will move away from Magnet 2.

2. **A transportation engineer works for a city. What is he MOST LIKELY to do for his job?**

   (a) Drive subway trains.

   (b) Repair city buses when they break down.

   (●) Decide where to put stop signs and traffic lights.

   (●) A transportation engineer would NOT work on any of these things.

3. **What would a transportation engineer **NOT** work on?**

   (a) Bridges and tunnels

   (c) Stop lights and stop signs

   (b) Roads and highways

   (●) Engines for trains and buses
Designing Maglev Systems Assessment continued

4. Which of the following statements is TRUE?
   - Some magnets have only one pole.
   - Magnets always repel other magnets.
   - Magnets always attract other magnets.
   - Poles that are the same repel each other.

5. What kind of work does a transportation engineer do? Choose the BEST answer.
   - Drive trains and buses
   - Construct and repair roads and bridges
   - Repair trains and buses when they break down
   - Make sure that roads, bridges, and trains are safe

6. A student places two magnets on a table exactly four inches apart. They slide towards each other until they meet in the middle. If she places the two magnets four inches apart again, but this time with a book between them, what will happen to the magnets when she lets go?

7. The nail is attracted to the horseshoe magnet pictured here, but the penny is not. What does this tell us about the nail and the penny?
   - The nail weighs less than the penny.
   - A flat object is more magnetic than a round object.
   - The nail and penny are made of the same material.
   - The nail and the penny are made of different materials.

8. Which pair of magnets would be MOST difficult to push together where the arrows show?
   ![Diagram of two pairs of magnets with arrows indicating direction of magnetic force]

9. The South pole of a magnet will REPEL:
   - All magnets.
   - Anything made of metal.
   - The North pole of another magnet.
   - The South pole of another magnet.

10. At work, a transportation engineer would probably NOT:
    - Drive trains that carry people and cargo.
    - Figure out how to make a highway safer.
    - Improve how well a subway system works.
    - Decide on the best place to put a crosswalk.
Engineering is Elementary

Designing Maglev Systems Assessment continued

A girl is testing the properties of magnets. She slides a magnet towards a metal paperclip, as shown in the picture, and measures the distance the paperclip travels to stick to the magnet. She records her results in a table shown below.

Use this information to answer questions 11 and 12.

11. If she repeats her experiment using an iron nail that is heavier than the paperclip, what will happen to the distance the iron nail travels to stick to the magnets?

- All the distances travelled will be greater.
- All the distances travelled will be smaller.
- All distances travelled will remain the same.
- The iron nail will NOT move at all.


<table>
<thead>
<tr>
<th>Magnet Type</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bar Magnet</td>
<td>10 cm</td>
</tr>
<tr>
<td>Ring Magnet</td>
<td>5 cm</td>
</tr>
<tr>
<td>Disc Magnet</td>
<td>15 cm</td>
</tr>
<tr>
<td>Strip Magnet</td>
<td>20 cm</td>
</tr>
</tbody>
</table>

12. Based on the table, which magnet has the strongest magnetic field?

- Bar magnet
- Ring magnet
- Disc magnet
- Strip magnet

13. This picture shows five ring magnets on a pencil. The magnets do not touch, but seem to float in the air. When the magnets are pushed together, they bounce back.

Which statement BEST describes what is happening?

- The magnets have opposite poles facing each other.
- The magnets have the same poles facing each other.
- The magnets floating higher weigh less than those floating lower.
- Some magnets have like poles facing and some have opposite poles facing.

14. A boy stacked two ring magnets on a peg. He made Ring Magnet A float over Ring Magnet B and measured the distance between them. What will happen if he wraps Ring Magnet A in cloth?

- Ring Magnet A will stick to the bottom magnet.
- The distance between Ring Magnets A and B will increase.
- The distance between Ring Magnets A and B will decrease.
- The distance between Ring Magnets A and B will stay the same.
16. A girl found a box containing two magnets. Only one magnet has markings showing its North and South poles. How could she identify the poles of the unmarked magnet?

- Stick both magnets together.
- Stick both magnets to a refrigerator.
- Sprinkle iron filings on both magnets.
- Check to see if aluminum foil sticks to both magnets.

17. A country is building a new train system. What is a transportation engineer MOST LIKELY to do to help?

- Repair the new trains when they break.
- Drive machines to construct the train tracks.
- Figure out what kinds of trains and train track to use.
- Improve the engines for the trains that will run on the tracks.

18. The diagram shows 2 bar magnets.

A girl moves the 2 magnets closer together. Which of the pictures below shows what is MOST LIKELY to happen?
Designing Maglev Systems Assessment continued

A Maglev transportation system is a way to get people and things from one place to another. It is made up of a vehicle and a track. The vehicle does not touch the track as it moves - instead it levitates (floats in the air) above the track.

A group of students are designing a Maglev transportation system to transport packages. They need to make the vehicle levitate as it is pushed along the track.

19. The students imagined the following designs. Which one shows a vehicle that might levitate?

20. The students created a design, made a plan, and built this model. They tested it, but it didn’t levitate. What should they do to solve this problem?

- Use stronger ring magnets.
- Flip the ring magnets so the North poles are up.
- Attach the ring magnets to the bottom side of the vehicle.
- Any of these ideas would work.

21. The students tried again and got the vehicle to levitate above the track. However, when they put a package on the middle of the vehicle, the vehicle sank onto the track. What happened?

- The strip magnets are too strong and attracted the vehicle.
- The package is magnetic, and it changed the magnetic field.
- The ring magnets are in the wrong place to hold the package on top.
- The ring magnets on the vehicle are not strong enough to lift the package.
Designing Maglev Systems Assessment continued

22. A boy designed a Maglev system to make a vehicle levitate (float in the air) over a track made of strip magnets. He set up his track and vehicle in four different ways. Which picture shows a vehicle that MIGHT levitate?

![Diagram of Maglev systems with different magnet configurations]

23. Which change to a working Maglev system will keep the vehicle at the SAME height?

- Flip all the magnets over.
- Add more magnets to the vehicle.
- Make the vehicle out of a lighter material.
- Replace the magnets on the vehicle with stronger magnets.

24. Why would you want to use strong magnets in a Maglev design?

- Strong magnets will help to keep the vehicle from toppling over.
- Strong magnets will help to keep the vehicle attached to the track.
- Strong magnets will help to levitate a vehicle higher above the track.
- Strong magnets will help to keep the vehicle moving faster along the track.

Question 1: adapted from MCAS 2008 - Grade 5.
Question 7: adapted from Virginia Standards of Learning Assessments, Spring 2001 - Science q. 36, Grade 3.
Question 11: adapted from NYSED Regents 2006 - Grade 4.
Question 13: adapted from MCAS 2006 - Grade 5.
Question 15: adapted from MCAS 2002 - Grade 5.
Question 18: adapted from MCAS 2004 - Grade 5.
For each question below, fill in the bubble for the BEST answer.

1. Choose the BEST answer. An environmental engineer:
   ① Repairs trucks, airplanes, and cars.
   ● Solves air, soil, and water problems.
   ② Designs bridges, roads, and tunnels.
   ③ Improves cell phones, computers, and televisions.

2. What might an environmental engineer do for his or her job?
   ① Study what whales eat.
   ② Design vegetable gardens.
   ● Find ways to clean up an oil spill.
   ③ Drive machines to cut down trees.

3. On a hot and sunny day, a boy poured a glass of cold water. A few minutes later, the glass was wet and slippery on the outside. How did the water get there?
   ① It rained.
   ● It condensed.
   ② It evaporated.
   ③ It leaked through the glass.
Engineering is Elementary

Designing Water Filters Assessment continued

4. What is an environmental engineer MOST LIKELY to do for her job?
   1. Create new kinds of fuels.
   2. Take care of wild animals.
   3. Develop man-made lakes and streams.
   4. Prevent damage to land, water, and seas.

5. At work, an environmental engineer is MOST LIKELY to:
   1. Test soil for contaminants.
   2. Design electric engines for boats.
   3. Design a new habitat for animals.
   4. Pick up glass, paper, and plastic for recycling.

6. Which is an environmental engineer MOST LIKELY to design?
   1. A zoo.
   2. A garden.
   3. A way to clean water.

7. Why is it important to stop pollution of the soil?
   1. Animals that live in the soil might die.
   2. Humans eat plants that have grown in the soil.
   3. When water flows through polluted soil it might become polluted.
   4. All of the above are reasons why it is important to stop pollution of soil.

---

Use the following diagram to answer questions 8 through 11.

8. Which change is occurring at stage 1 in the diagram?
   1. Water is changing from a gas to a solid.
   2. Water is changing from a liquid to a gas.
   3. Water is changing from a solid to a liquid.
   4. Water is changing from a liquid to a solid.

9. Where in the diagram is evaporation taking place?
   1. At 1
   2. At 2
   3. At 3
   4. At 4

10. Where in the diagram is condensation taking place?
    1. At 1
    2. At 2
    3. At 3
    4. At 4

11. Where in the diagram is precipitation taking place?
     1. At 1
     2. At 2
     3. At 3
     4. At 4

12. Which of the following filters would work BEST to QUICKLY remove large leaves from water? A filter made of:
    1. Sand
    2. Cotton balls
    3. Paper
    4. Metal screen
Designing Water Filters Assessment continued

13. Which of the following could become water pollution?
   - Waste from farm animals
   - Oil spilled by broken machines
   - Fertilizer that people put on grass to make it grow
   - All of the above

14. What does an environmental engineer think about?
   - How to protect habitats.
   - How to prevent pollution.
   - How to make water safe for people to drink.
   - All of the above.

15. Which of the following is LEAST LIKELY to be the job of an environmental engineer?
   - Designing a technology to clean up pollution
   - Figuring out where soil pollution is coming from
   - Running and repairing a machine that cleans up pollution
   - Helping a town figure out how to clean up river pollution

16. A lake becomes polluted. What living things are affected by the dirty water in the lake?
   - The plants around the lake
   - The fish that live in the lake
   - The people who live near the lake
   - All of the above

17. Which of these is LEAST LIKELY to contaminate water?
   - Dirt
   - Dog droppings
   - Trash
   - Soap from washing clothes

18. What could add pollution to the soil?
   - Factories
   - Farm animals
   - Parking lots
   - All of the above

19. Which of the following could add contaminants to water?
   - Dogs
   - Boats
   - Birds
   - All of the above

A girl has designed a water filter using a metal screen. She wants to clean brown water with lots of small particles floating in it. She pours the dirty water through, but it does not change.

20. What would be the BEST thing she could do to remove the small particles?
   - Scoop out the particles with a spoon.
   - Use a filter material with larger holes.
   - Use a filter material with smaller holes.
   - It is not possible to remove the small particles.

21. What would be the BEST thing she could do to remove the brown color?
   - Clean the water with soap.
   - Use a filter material that is softer.
   - Use a filter material with smaller holes.
   - It is not possible to remove the brown color.
Designing Water Filters Assessment continued

2. Two students make a water filter. A diagram of their filter is shown below. They pour murky brown water with leaves in it into the top of their filter. The leaves don’t come through, but the water that comes out is still brown. What is the MOST LIKELY problem?

- Only chemicals can remove color from water.
- A filter can NOT change the color of the water.
- The filter is not catching things that are very tiny.
- The sand in the filter is turning the water brown again.

3. What can the students do to help get the brown color out of the water?

- Add soap to the water.
- Remove the sand from the filter.
- Add more sand to the filter.
- The students can not get the brown color out of the water.

4. The students try adding more of each of the materials to their filter. A diagram of their new filter is shown to the right. They pour dirty water into the top of their filter. The water fills up the top of the filter and comes out the bottom too slowly. What is MOST LIKELY the problem?

- Too much sand is blocking the water.
- Too many screens are blocking the water.
- Too much paper is soaking up all of the water.
- Too much cotton is soaking up all of the water.

5. Which of the following BEST describes the water cycle?

- Collection → Evaporation → Precipitation → Condensation → (Cycle starts over)
- Condensation → Evaporation → Precipitation → Collection → (Cycle starts over)
- Precipitation → Collection → Evaporation → Condensation → (Cycle starts over)
- Evaporation → Precipitation → Collection → Condensation → (Cycle starts over)

Question 8 adapted from MCAS, 2009, Gr. 5
Figure 23. Designing Model Membranes Assessment

Filled circles indicate correct answers

For each question below, fill in the bubble for the BEST answer.

1. Which of these is something that membranes do in nature?
   - They help living things to find water.
   - They keep animals warm when it's cold out.
   - They protect plants and animals from predators.
   - They keep harmful things out of animals' bodies.

2. A salamander is an amphibian. How does a salamander get water?
   - Through its skin
   - Through its lungs
   - Through its gills
   - All of the above

3. A company is designing a new kind of airplane that can soar a long way without fuel. How would a bioengineer help?
   - He would fix the new airplane engines when they break.
   - He would design the airplanes so they don't pollute the air.
   - He would study birds and fish to get ideas for the new kind of airplane.
   - He would NOT help a company to design a new kind of airplane.

4. Which of the following is an example of a membrane?
   - Skin
   - Eyes
   - Ears
   - Mouth

5. What does a habitat provide for an animal or plant?
   - Air
   - Shelter
   - Food
   - All of the above
Designing Model Membranes Assessment continued

6. Which is true?

- Both plants and animals have membranes inside them.
- Plants have membranes inside them, but animals do not.
- Animals have membranes inside them, but plants do not.
- Neither plants nor animals have membranes inside them.

7. Some types of trees are able to survive the heat of a forest fire. Which of these structures would BEST help a tree to survive a fire?

- Thick bark
- Large leaves
- Thick trunk
- Shallow roots

8. Choose the BEST answer. Bioengineers:

- Take care of sick people and animals.
- Fix engines so they don’t pollute the air.
- Study nature to get ideas for how to solve problems.
- Design technologies that don’t hurt the environment.

9. The pictures below show the change in the fur of an arctic hare from summer to winter.

Which of the following statements BEST describes how this change helps arctic hares?

- It lowers their body temperature.
- It protects their eyes from sunlight.
- It helps them move on slippery ice.
- It makes them less visible to predators.

10. Rose plants have sharp thorns on their stems. How do thorns help rose plants to survive?

- Thorns protect the plant from harm.
- Thorns help the plant to get moisture.
- Thorns anchor the plant in the ground.
- Thorns support the stems and branches.

11. For his or her job, a bioengineer might:

- Fix boat engines.
- Take care of sick animals.
- Clean up pollution in a lake.
- Study nature to get ideas for new technologies.

12. Cloth is like a membrane because:

- It is made of fibers.
- It is used to make clothing for people.
- Only certain things can pass through it.
- Cloth is NOT like a membrane.

13. The leaves of some plants have tiny slippery bumps so that water runs off them quickly, washing away dirt. Studying the leaves of these plants MOST LIKELY would help someone to design:

- A raincoat
- A wash cloth.
- Grass leaves
- A dishwasher.

Question 7: adapted from MCAS 2007 STC Assessment -- Grade 5
Question 9: from MCAS 2003 STC Assessment -- Grade 5
Question 10: from MCAS 2006 STC Assessment -- Grade 5
14. A tuna is an ocean fish that eats small, fast-moving fish that other fish can’t catch. Which of the following structures MOST helps a tuna to catch small, fast fish?

- Large fins
- Small gills
- Sharp teeth
- Tough scales

15. A window screen is like a membrane because:

- It is human-made.
- It can be made out of metal or plastic.
- Some things can go through and others can not.
- A window screen is NOT like a membrane.

16. A bioengineer is MOST LIKELY to help design a technology that:

- Will protect the environment.
- Will help to protect animals and people.
- Will be used outdoors in a natural place.
- Works in the same way as something in nature.

17. A squid is an animal that lives in the ocean. It pumps a stream of water out of its body, causing it to move quickly. Which of the following moves in a way MOST similar to the squid?

- A bus
- A train
- A rocket
- A helicopter

18. The picture below shows the foot of a kind of bird. What kind of habitat is this bird MOST LIKELY to live in?

- Desert
- Meadow
- Freshwater lake
- Tropical rain forest

19. Lizards use the sticky pads on their feet to hang on to trees. Observing lizard feet MOST LIKELY would help someone to design:

- Stronger glue.
- Faster running shoes.
- More comfortable hiking shoes.
- Observing lizard feet would NOT help with a design.

20. Someone wants to design a faster boat. To look at the way nature might solve the problem, one of the BEST things for her to study is:

- Bees entering their hives.
- Fishes swimming in the sea.
- Seaweed floating in the ocean.
- She would NOT study things in nature.

21. What in nature MOST LIKELY gave people the idea to design a parachute?

- A goose flying long distances
- A cat jumping down from a fence
- A leaf falling gently through the air
- A hot air balloon moving slowly through the air
Designing Model Membranes Assessment continued

22. Which of these is designed to do the same sort of thing as a natural membrane?

- Bowl
- Tea bag
- Cardboard
- Aluminum foil

23. Which of these is designed to do the same sort of thing as a crab shell?

- Pliers
- Spider
- Straw hat
- Suit of armor

24. Students want to design a model membrane that lets water drip through slowly. Which of these materials would be BEST to choose for designing the membrane?

- A sponge
- Cheese cloth
- Metal screen
- A sheet of plastic

25. A man is helping to design a very fast train. To get ideas, he is MOST LIKELY to study:

- Engines used in very fast cars.
- Fuel used for rockets that fly into space.
- Birds that fly and dive quickly through the air.
- Trains that pull lots of heavy stuff for a long distance.

In the picture, Liquid A and Liquid B are both clear liquids, like water. However, if they are mixed together, the liquid mixture becomes purple.

A student puts Liquid A in a clear plastic bag and Liquid B in a cup. He puts the bag into the cup. After an hour, the liquid in the cup turns purple, but the liquid in the bag stays clear.

26. What MUST be happening?

- Liquid A can pass through the plastic bag but Liquid B cannot.
- Liquid B can pass through the plastic bag but Liquid A cannot.
- There must be a hole in the bag so that Liquid A and Liquid B can mix.
- Liquid A and Liquid B can both pass through the plastic bag to mix together.

27. In this experiment, which is the model membrane?

- The cup
- Liquid A
- The plastic bag
- There is no model membrane in this experiment
Figure 24. Seeing Animal Sounds Assessment

Filled circles indicate correct answers.

For each question, fill in the bubble for the BEST answer.

1. **What is sound?**
   - Vibrations
   - A form of energy
   - Something that can travel through any kind of stuff
   - All of the above

2. **The volume of a sound describes:**
   - how loud it is.
   - how long it lasts.
   - how much it echoes.
   - how high-pitched it is.

3. **An acoustical engineer might design:**
   - a computer.
   - a hat with ear flaps.
   - scientific instruments to record animal sounds.
   - an acoustical engineer would not design any of these.

4. **The pitch of a sound is:**
   - how loud the sound is.
   - how high the sound is.
   - how long the sound lasts.
   - all of the above.

5. **Covering your ears with your hands will probably _____ sounds.**
   - damp
   - increase
   - vibrate
   - not affect

6. **Acoustical engineers are helping to design a concert hall. What are they MOST likely to work on?**
   - The lights that shine on the stage
   - The musical instruments the musicians play
   - The machines to open and close the curtains
   - The material covering the walls to stop echoes
Seeing Animal Sounds Assessment continued

Graph A and Graph B show diagrams of two different sounds. Use the diagrams to answer questions 7 to 10.

7. What property of sound do both of these graphs show?
   - Pitch
   - Volume
   - Music
   - All of the above

8. Which sound reaches a higher pitch?
   - The sound shown by Graph A.
   - The sound shown by Graph B.
   - Both sounds reach the same pitch.
   - These graphs do not show pitch.

9. Which sound reaches the highest volume?
   - The sound shown by Graph A.
   - The sound shown by Graph B.
   - Both sounds reach the same volume.
   - These graphs do not show volume.

10. Which sound has a higher volume when it starts?
    - The sound shown by Graph A.
    - The sound shown by Graph B.
    - Both sounds start with the same volume.
    - These graphs do not show volume.

11. The duration of a sound is:
    - how high the sound is.
    - how loud the sound is.
    - how long the sound lasts.
    - where the sound comes from.

12. What can sound travel through?
    - air
    - the ground
    - walls
    - all of the above

13. When a sound has a short duration it means that:
    - the pitch of the sound is low.
    - the sound does not last long.
    - the sound does not have much energy.
    - the vibrations making the sound are fast.

14. What does it mean when a sound has a high volume?
    - The sound has a pitch.
    - The sound has lots of energy.
    - The sound lasts a long time.
    - All of the above.
Seeing Animal Sounds Assessment continued

15. The picture shows a guitar. How could you make one of the strings on the guitar have a higher pitch?
   - Loosen the string
   - Tighten the string
   - Play the guitar louder
   - Replace it with a thicker string

16. What happens when you make a string on the guitar have a higher pitch?
   - The string gets longer
   - The string gets louder
   - The string vibrates faster
   - The string vibrates more slowly

17. Which string on the guitar will have the lowest pitch?
   - The thickest string
   - The thinnest string
   - The shortest string
   - The most stretched string

18. A student is playing a violin. She plays a note that lasts 5 seconds. She then plays the same note for 2 seconds. What is different about the two notes?
   - Pitch
   - Volume
   - Duration
   - The notes are the same

19. A tuning fork makes a loud sound if you strike it against a table. What could you do to make the sound quieter?
   - Put the tuning fork into water
   - Wrap the tuning fork with cloth
   - Put clay on the ends of the tuning fork
   - All of the above

20. If you hear a very loud sound outside, can you completely stop the sound from coming into your house?
   - Yes, by playing music very loudly
   - Yes, by closing all windows and doors very tightly
   - No, you can only make the sound quieter
   - No, the sound will find a crack where the air comes in

21. Which of the following is a way to damp sounds from a radio?
   - Put the radio under a blanket
   - Turn down the volume control
   - Cover your ears with your hands
   - All of the above

22. How are higher-pitched sounds different from lower-pitched sounds? Higher-pitched sounds:
   - are louder
   - last for a longer time
   - are made by faster vibrations
   - all of the above
Seeing Animal Sounds Assessment continued

3. Which of these graphs show a pitch decreasing at least once?
   - Graphs A and D
   - All of the graphs
   - Graphs A, B, and D
   - None of the graphs

4. Which of these graphs could represent the same bird song?
   - Graphs A and B
   - Graphs A and D
   - Graphs B and C
   - None of the graphs

5. Which graph shows a sound where the beginning pitch is higher than the ending pitch?
   - Graph A
   - Graph C
   - Graph B
   - Graph D

6. Which graph shows a sound where the beginning pitch is lower than the ending pitch?
   - Graph A
   - Graph C
   - Graph B
   - Graph D

7. A man is designing a system to represent whale sounds. What are some things he should think about?
   - What properties of the whale sounds are important to represent.
   - What kinds of systems other people have designed to represent sounds.
   - How to make the system for representing sounds easy for others to understand.
   - All of the above.