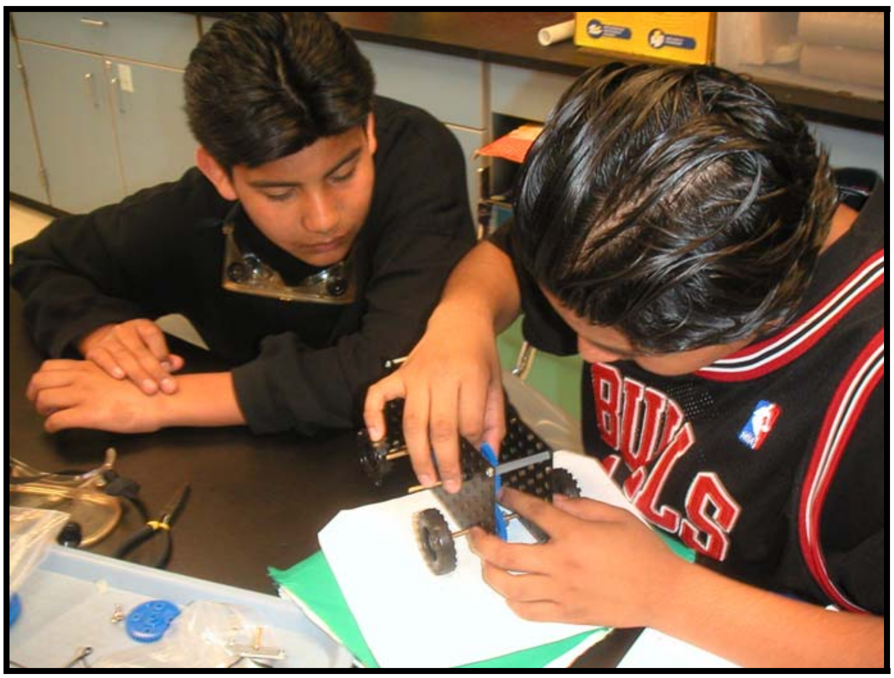
EVALUATION OF THE SPRING 2006 MIDDLE-SCHOOL IMPLEMENTATION OF THE EOFNJ PROJECT: THE AWIM PILOT



Dr. Susan Lowes
Bernadette Sibuma
Institute for Learning Technologies
Teachers College / Columbia University
June 20, 2006

The middle-school component of the EOFNJ project is an adaptation of the Society of Automotive Engineers' A World in Motion: The Design Experience – Challenge 2 (AWIM) curriculum. The pilot began with a workshop attended by twelve teachers from eleven New Jersey schools; two teachers (from one school) dropped soon after and are not included in the data below. The remaining ten teachers taught 6th, 7th, and 8th grade as follows:

Grade	# teachers	Comments
6th	3	1 technology
7th	2	
8th	3	1 technology
Mixed	3	1 Computer Education; 1 technology enrichment; 1 special education

They came from across New Jersey, with an emphasis on the lower performing districts:

District	# schools
A	2
B	2
C/D	1
D/E	1
F/G	3
G/H	2

The AWIM curriculum was condensed into five curriculum units that would be taught over four weeks. The evaluation had several components: teachers were asked to complete a short survey at the end of each of the five units and another survey after the curriculum had been completed. In addition, although the curriculum as written had a number of embedded assessments, it had no pre- or post-tests. We therefore added one pre-assessment on gears and two pre-post assessments on engineering and technology that we adopted from the elementary curriculum.

END-OF-UNIT SURVEY RESPONSES

After teaching each unit, the teachers were asked to respond to a survey that asked how long the unit took, whether the background material was adequate, and what changes they had made, what additional activities they might have added, whether they taught the unit differently for different classes, and if they had any other suggestions. The data that follows is organized by unit, beginning with an analysis of the time spent on each unit, the teachers' assessment of the adequacy of the materials, and then their responses to open-ended questions about changes they made, activities they added, adaptations to different types of students, and additional comments. As of the time of writing, different numbers of teachers have taught the different units, so the number of responses differs.

In general, teachers devoted many more periods to the curriculum than was in the implementation schedule (the numbers in brackets in the table below are the number of days, assuming one class period a day, that were allocated to each activity; HW is homework), but the amount of time, as measured in class periods, varied widely, as did whether the activities were used in class or as homework. Teachers often did activities that were designed as homework in class, which added to the time spent on the unit. The time pressure led some of them to forego some activities, particularly toward the end (the presentations).

In general, the teachers considered the background material and the student materials adequate, but they made some changes to both. Some of their suggestions might be incorporated into a "Practical Suggestions" sheet if the curriculum is offered again.

Here is the unit by unit discussion:

Unit 1: Set Goals

[Designed for 2 periods total]

If you did these activities in class how many class periods did you use?
If you did these as homework check that choice.

	Less than 1 period	1	2	3	4 or more	HW	Did not do
Reading and Evaluating the Request for Proposals (RFP) [1]	0	3	2	1	0	2	0
Designing a Team Name Logo and Slogan [HW]	0	1	1	1	2	4	0

Identifying the Customers [HW]	0	2	2	0	0	3	1
Seeing the Big Picture [.5]	1	3	1	1	0	0	0
Creating a Design Checklist [.5]	1	4	1	0	0	0	0
Using Design Logs [0]	1	3	2	0	0	0	0

Materials

	Yes	Somewhat	No
Was the background material adequate for you as a teacher?	5	1	0
Were the student materials adequate?	4	2	0

What changes did you need to make so that this unit would work in your classroom?
I found creating transparencies helpful to go over the material. After the students completed their own work, we filled in the overhead as a class.
Survey sheet addressed one person at a time. We designed check list for simplification using the survey form given as overview. I had difficulty getting a bike so we had to limit discussion to poster and internet view not actual bike.
1. Added a few worksheets. 2. Added a parts checklist.
My students needed their tasks broken down into smaller incremental steps.
I think the RFP was difficult for my class, probably related to their reading level. I really had to help them break it down.
My greatest challenge has been due to the fact that my class is a pull-out program. With the GEPA just around the corner many of the academic teachers are giving the students a hard time about missing class. The BOE, administration and parents have sanctioned the program as pull-out. Parents and students have signed an agreement to make-up missed work. Make-up classes for the design teams have been scheduled into my program and the principal is working on getting more cooperation from some of the academic teachers. A number of students are making use of the make-up times and, hopefully, the rest will soon follow suit.
Took a little longer to complete because of short class periods.

I had to shorten the amount of time that I could spend on each part because I have a limited amount of time.

Did you do any additional activities, either from other parts of the AWIM curriculum or of your own, during this unit?
Yes 1. we continue to have the weekly assignment - technology news article day. In this activity the students use the internet to locate an article on some technically related subject, print the article and make a written review of the article. 2. we are making a video documenting the process.
Several of the students wish to modify the kit pieces to better fit their design plans. In order to accommodate their interests, I have worked with them on chain drives, shortening axles and using different motors. We also used the soldering gun to adapt one of the motors, allowing it to be powered via a battery pack.
I did bring in my bicycle. It was very helpful. We spent some time measuring the diameter of the bicycle tire to quantify the motion. If the tire is 72 inches in diameter, 2 revolutions move the bike twice as far. They had some trouble with the concept before we did that.
Used internet for bike gears. Discussion in class about RFP and who this is actually used in business. Discussin on how "marketing" or "advertising" plays a vital role in big business.
We covered ratios and proportions from the textbook

Were there any major differences in how you taught the unit in different classes?
I did this project is several of my classes. The only class where there were some major differences was my "in-class support class. I have 1/3 of the class as special educ. students. Instead of 3 person teams, I have some that are 2 man and two other students working independently because they could not work cooperatively with another person for various reasons. I also selected this class and another class to work with a small deaf group of students at the Philadelphia School for Deaf in Philly. It is working out very well.

I had one of my fluently bilingual students translate the materials for the two non-English speaking students.
Afternoon classes-not as much time spent on Creating a Checklist, Seeing the Big Picture. Afternoon classes are much shorter and usually have numerous interruptions.

Any other issues, comments, or suggestions regarding this unit?
I would like to see the AWIM kits include a battery pack alternative for the car kits. Running the vehicles while attached to power cords limits mobility and detracts from the experience.
The initial exploring of the gears and how they rotate was fun and enlightening for the students. I would have liked to have designed a board with moveable gears for them to use to model the gear patterns. It was hard for them to manipulate then by hand alone.
I was surprised at how many students wanted to modify the project - before they even touched the kits - with things like magnets. Some groups started with ideas of creating hovercrafts and were generally disappointed that they were limited to the kits (wheeled vehicles). When I explained the chassis they could add, it helped. I did enjoy their enthusiasm.
I felt like I kept having to search for things in the binder. I thought that the materials should have been in order a little more than they are. I felt like some parts should have been before others and I felt like even when I was sticking to the curriculum, I had to flip around in the binder a lot and felt very unorganized.
Additional activity sheets that connect with the curriculum would be great.

Unit 2: Build Knowledge

[Designed for 9 periods total]

If you did these activities in class how many class periods did you use? If you did these as homework check that choice.

	Less than 1 period	1	2	3	4 or more	Homewrk	Did not do
Looking at Gears in Bicycles [.5]	3	1	0	0	0	1	0
What We Know About Gears [.5]	3	1	0	0	0	0	0
Introducing Gear Materials [.75]	1	2	1	0	0	0	0
Concept Maps [.25]	2	2	0	0	0	0	0
Recording Gear Rotations [1]	1	2	1	0	0	0	0
Adding a Motor and Wheels [1]	0	0	2	1	1	0	0
Measuring Performance: Speed and Wheel Rim Force [1]	0	0	1	1	2	0	0
Compound Gear Trains [1]	0	0	0	1	2	0	0
Measuring Performance: Compound Gear Trains [2]	0	0	0	2	2	0	0
What We've Learned About Gears [.50]	2	1	1	0	0	0	0
Concept Maps Revisited [.25]	3	1	0	0	0	0	0
Basic Understanding of Gears (assessment) [.25]	2	1	1	0	0	0	0
Conducting Interviews [HW]	1	1	1	0	0	2	0
Conducting Surveys [HW]	0	2	1	0	0	1	1

Materials

	Yes	Somewhat	No
Was the background material adequate for you as a teacher?	3	1	0
Were the student materials adequate?	3	1	0

What changes did you need to make so that this unit would work in your classroom?
The time was extended from the 2 weeks on the implementation schedule.

More time to explore the gear combinations. Measuring rim force also took longer. I preferred to only use one spring scale station. I would give the students more practice with the spring scales in the Forces Unit I did prior to this project.
We spend a lot of time with gears. I wanted the students to have free exploration. I did not model anything for this reason. I think it was time well spent.

Did you do any additional activities, either from other parts of the AWIM curriculum or of your own, during this unit?
I repeated instruction from the bicycle activity to help the students understand the difference between 9:1 and 1:9 driver vs driven. They still mix up this concept.
Yes, I gave the students additional information about spring scales and force.
Again the free exploration allows my students to investigate their ideas without being influenced by my view. Many of their ideas were incorrect but by trying them out they came to that realization on their own. My job was to get them to verbalize what they thought and to get them to try it out and analyze it.

Were there any major differences in how you taught the unit in different classes?
Afternoon classes suffered more interruptions and had a little less time for some of the activities.

Any other issues, comments, or suggestions regarding this unit?
These lessons went very well. The pull-out nature of my program continues to be a challenge; however, the students are getting into the habit of utilizing the alternative make-up times on a weekly basis. One student from the special needs program was removed by the principal due to behavioral and work study issues.
Axles are too sharp. Many students suffered cuts. Many problems when compound gear trains being built. Many of the gears do not stay on the drive collars and come loose when the motor drives all the meshing gears.
The students really enjoyed it, even though they did get frustrated at times.

I found building and measuring compound gear trains difficult to implement. The students had a difficult time building compound gear trains that would move.
Compound gears was a challenge. Some of my students would have liked me to tell them what configurations work...of course I won't. I want them to think out ways and try them without my help.

If you did these activities in class, how many class periods did you use? If you did these as homework, check that choice.
Integrating and Applying What We Know - Less than 1 period

Unit 3: Design

If you did these activities in class how many class periods did you use? If you did these as homework check that choice.

	Less than 1 period	1	2	3	4 or more	Homewrk	Did not do
Integrating and Applying What We Know [.5]	2	0	1	0	0	0	0
Writing a Design Brief [.5]	2	2	0	0	0	0	0
Designing a Gear Train for the Prototype [1]	0	1	1	1	1	0	0
Building a Prototype [1]	0	2	0	0	2	0	0
Performance Testing the Prototype [1]	1	2	0	1	0	0	0
Redesigning the Prototype [1]	0	1	2	0	0	0	1
Exploring Body Materials HW]	2	0	1	0	1	0	0
Drawing Body Designs [HW]	1	2	1	0	0	0	0

Materials

	Yes	Somewhat	No
Was the background material adequate for you as a teacher?	3	1	0
Were the student materials adequate?	2	1	0

What changes did you need to make so that this unit would work in your classroom?
Condensing of some of the activities--seemed to be repetitive. Most students did not need to re-design. Only a few groups changed their designs. Did Exploring Body Materials in class.
Some of the students opted to modify the basic components of the AWIM kit by adding their own motors, belts for a belt drive, cutting down the matrix board, etc. Most changes were successful. Some did this additional work at home. Surprisingly, the most difficult portion of the project has been the written presentation pieces. These kids would much rather work hands-on than write descriptive paragraphs.
I needed more visuals so I created a powerpoint on gears with animation to capture their attention. I was unsuccessful at obtaining additional manipulatives due to budget constraints.
The designs on the body were printed to a color inkjet printer using MS Power Point or MS Paint, instead of hand-painting the projects.
I did need to bring in a supply of materials for the students (economics). After discussing design possibilities, I bought in foam core board, skewers (wooden), fun foam sheets, and aluminum foil. I do have to do more in class due to a lack of support/resources at home. Students did not really meet after school to advance the project.

Did you do any additional activities, either from other parts of the AWIM curriculum or of your own, during this unit?
Yes, as per my comments above, several student groups met at home to modify their kit designs.
I did return to the bicycle in my room to model driver vs driven. Unrelated to the project itself, I did have a review day because we paused the project waiting for the public relations rep. The students then needed a refresher after the several week break.

Were there any major differences in how you taught the unit in different classes?
Again condensed in afternoon classes because of scheduling restraints/interruptions.
The older children (8th grade) moved a little more quickly when working with the project than the 6th grade group. But the 6th grade group showed greater enthusiasm.

Any other issues, comments, or suggestions regarding this unit?
No, the unit was easily adaptable to our needs and interests.
If I have the time I would create more posters, more detailed steps and examples of the products at each step For instance the design brief.
Time is a definite factor. While I think they could have used a little more time to tweak their designs, they did well in the time they had. Doing the project in a fixed period does make sense.

Unit 4: Build and Test

If you did these activities in class how many class periods did you use? If you did these as homework check that choice.

	Less than 1 period	1	2	3	4 or more	Homewrk	Did not do
Constructing the Body [1]	0	0	2	0	2	1	0
Assembling Testing Adjusting the Final Design [1]	0	2	0	1	1	1	0
Preparing the Oral Presentation [1]	0	0	2	0	0	0	1

Materials

	Yes	Somewhat	No
Was the background material adequate for you as a teacher?	3	1	0
Were the student materials adequate?	3	1	0

What changes did you need to make so that this unit would work in your classroom?
I had to drop the oral presentations as the I was absent due to illness and the cycle ended before the children could pull a final presentation together.
Many students were ready for their final designs and did not do much redesigning. Students built some very intricate and some very basic body designs. Not many did testing because they had completed their design briefs and tested for that.
Any changes to the construction of the vehicles were entirely on the part of the students.
I did supply construction materials that we had discussed. For various reasons (economics), many students could not provide what they required. I made available foam core board, fun foam, pipe cleaners and wooden skewers (long, strong toothpicks), aluminum foil, and lots of shoe boxes (cardboard stock). Also hot glue gun and ‘tacky” glue.

Did you do any additional activities, either from other parts of the AWIM curriculum or of your own, during this unit?
No, as a pull out program I needed my 2 periods a week to get through the basics.

Were there any major differences in how you taught the unit in different classes?
Afternoon classes had slightly less time because of scheduling restraints.

Any other issues, comments, or suggestions regarding this unit?
The experience has, thus far, been very positive!
It must be made clear to the students, early on, that they will not be allowed to glue or tape directly to the frame. This caused some problems for some of the students’ designs. They had trouble with the concept of “hanging” the body on the

frame. I modeled with a shoebox, but I will try to create a more complicated model. Also I will see what the students donate at the end - nothing into the garbage!

Unit 5: Present

If you did these activities in class how many class periods did you use? If you did these as homework check that choice.

	Less than 1 period	1	2	3	4 or more	Homewrk	Did not do
Preparing Final Presentations [1]	1	1	1	2	0	1	0
Student Group Presentations [.75]	0	0	2	0	1	0	1
Reflecting on the Engineering Design Experience [.25]	1	2	1	0	0	1	0

Materials

	Yes	Somewhat	No
Was the background material adequate for you as a teacher?	3	2	0
Were the student materials adequate?	3	2	0

What changes did you need to make so that this unit would work in your classroom?
I prepared a rubric based on the design brief specifications and issued them to the student groups before they prepared for their presentations.
I created a rubric for scoring criteria, peer evaluation, and reflection questions.
We followed the standard plan for the most part.
I created a bullet point outline from page 258. We brainstormed but I felt the amount of material we wanted them to comment on was too broad without some support.

Did you do any additional activities, either from other parts of the AWIM curriculum or of your own, during this unit?
We added additional gear research activities.
Students presented via MS PowerPoint slideshows that they completed during tech design class, after-school computer time, and at home.
No, but I am planning on returning to the computer lab to have them publish their results in another format. I'm working with the technology teacher on the format, possibly a poster on the web.

Were you pleased with the final results, including the Reflections?
Many student groups were warned repeatedly to prepare for their presentations but did not do much preparation away from school. A few did very nice powerpoint presentations but most seemed to “wing it,” which did not work very well.
The students did a nice job overall. It took me MUCH longer than I had planned. The gear set-up really troubled the students. Even then more time should have been given to practice their presentations and polish presentation skills.
The administration and I were extremely pleased with the final presentations of this cross graded/cross classification group of seventh and eighth graders.
Yes very much.

Were there any major differences in how you taught the unit in different classes?
Morning classes a little less direct instructions-able to self-motivate.

Any other issues, comments, or suggestions regarding this unit?
I still have issues with the handling of the materials. We needed needle nose pliers and tools to manipulate the parts. Many students got one gear configuration to work and then stuck with that and didn't even try anything else. Most of them went for torque until they actually started putting the gears together.

As stated in earlier assessments, MacKinnon School in Wharton, NJ ran this program as a part of the pull-out G/T classes. As a result, two eighth grade participants were frequently so behind in their ILA work that they were not permitted to attend the technology pull-out class. Unfortunately, this resulted in one less participating team in the final presentation phase.
I don't know how more than one class could utilize the same kit. I would love to know how teachers with more than one class handled the logistics of that.

FINAL SURVEY RESPONSES

After they had taught the entire curriculum, the teachers were asked to respond to a survey that asked some summary questions. To date, six teachers have done so. Below are their responses, organized by question. They show that the curriculum was very adaptable: it was used in different ways by different teachers, depending on their circumstances and their teaching styles. It thus proved to be very flexible; at the same time, this created certain challenges for the teachers.

They all liked the curriculum, but they liked different things about it:

Overall, what did you as a classroom teacher like most about the AWIM curriculum?
The excitement the students had when they completed the project
The hands-on materials provided a tremendous opportunity for students to experiment with different gear ratios and designs.
The number one thing I liked the most about the AWIM curriculum was the workbook. The workbook moved the program in a constant direction. The workbook made implementing the program very straight forward. The number two thing I liked about the AWIM curriculum was the “kit.” Simple and to the point.
The curriculum enhanced and supported our curriculum extremely well. Students were engaged. They saw a well-rounded and purposeful program rather than isolated hands-on activities.
I felt it was an engaging project that covered a wide range of material; Science, Math, Social Studies. It tied in very nicely with our Science unit on Forces.

Probably the best thing about it was the "level playing field" for the students. They all had the same materials and an equal chance of success. The parents didn't do the project for them, being affluent was not an advantage; most of the work was in school.
The best part of the AWIM curriculum was the variety of activities to choose from and the range of subject areas.

Only one said she/he would not teach it again, and that was because of time constraints:

If you would not teach this again, why not?
This was with the advanced students and they had trouble manipulating the parts. It too much longer than I planned. I think it would take even longer with my other classes. I would like to do it again, but I will have to condense the time and get better tools.

All but one of the teachers reported that they explicitly taught the design process, although they were not all sure that the students understood it:

Do you think most of your students understood what the engineering design process is by the end of the curriculum? Do they understand the difference between this and the scientific method?
I think the students approached this the same way they approach using the scientific method-they considered the goal to be solving the challenge of the RFP and made a plan to solve that problem
They certainly understand the design process. Since I do not have them for science, I am not sure about their ability to differentiate the two.
Most students showed an increased awareness of what the design process is. Maybe one or two students could discuss the difference between the design process and the scientific method.
Yes. We spend a lot of time discussing this. I also allowed the students to do free exploration as we went and it certainly was worth it. It allowed them to discover for themselves rather than have me model or direct them.
I think they understand the process, but I think they would have difficulty differentiating between them. Perhaps a Compare/Contrast activity would be

appropriate - Venn Diagram?
Some might have remembered from when we went through the steps at the beginning of the year.

Some had themes for the toys and some did not:

Did you have a theme for the toys your classes constructed? If so, what was it?
Yes, they had to be members of the animal kingdom.
Yes, each team had a company name and toy name.
The students used whatever theme they felt the "target audience" wanted.
No - they came up with all sorts of ideas on their own. We did discuss thinking outside the box...not always thinking "car" per se. I was impressed with what they are coming up with.
No.
No theme, personal choice for toy design.

Some found that it integrated directly into their curriculum, but for others it was new material:

Did you use this curriculum to reinforce concepts you were already teaching, to teach new concepts, or both? Was it integrated with another topic (i.e., physical science) or on its own? How did this work out for you?
This directly followed our Forces Unit and worked very well. We had covered Newtons, mechanical advantage and similar topics. I think this really gave them concrete examples and helped me teach the concepts.
This curriculum worked well for me, as I teach techy ed. I hope to include this curriculum in the program I am writing for next year.
It was both. We teach energy, machines and motion in 8th grade. This allowed students to expand upon that basic knowledge and actually apply it in a meaningful way.
Teach new concepts of gear trains and gear ratios. Reinforced engineering design process taught earlier in the year.

N/A--This class was a pull-out part of the G&T programming in the school. Eighteen students from grades 7 and 8 were referred to the program by their science teachers, guidance recs, and principal's approval.
This was pretty much on its own. The curriculum for 7th grade this year is mostly life science. I think it would be great integrated into physical science and I plan to use it that way next year. It worked out well, overall. The students seemed to get a lot from the project.

Most created additional support materials, but again, they all did this differently:

Did you need to create any additional curriculum support materials? If so, what were they?
The only additional materials I used were student check lists. These were used to help students organize their activities so that they arrived at a completed project by the end of the 7 week exploratory cycle.
We redesigned the design sheet. I actually took apart a frame and traced it to actual size. This was very beneficial for their drawing because it made them more accurate. They were in proportion.
The best thing I did was create overhead transparencies of many of the worksheets.
Yes, I used a rubric for the scoring of the final project and quizzes along the way as well as gear ratio information sheets.
Rubric for presentations and answer keys for some activities.
I used the teacher guide page 258 to create a guide for the Reflection. Finally I showed segments of the video, but I was not happy with the results. I would show less of it next time. The part about counting the rotations of the gears and compounding was helpful.
No, there was ample material within the kit from which to select.

In general, the curriculum went over well with girls, but there seems to have been some initial resistance:

Did you see differences between girls and boys in how much they liked the

curriculum, how well they did, or anything else?
The girls voiced that they were intimidated at first and thought the boys' teams would win, but as they worked they realized that they could do this and the girls' teams actually beat the boys.
At first it was an issue, the girls felt it was a “boys” project. Over time I think we really turned the girls around and they did very well. In groups that were coed I did see a tendency for the boys to try and dominate the actual building of the toy.
The girls seemed to like AWIM better that the old curriculum. Gender did not seem to be much of an issue when it came time to review the projects.
As with anything there are some who are less motivated than others but for the most part as we progressed everyone became competitive. I saw some girls really get into this which surprised me.
No, the students worked equally well.
Most boys seemed to enjoy it more than most girls.

They were all able to relate the concepts and materials covered to the New Jersey Standards, including technology, math, and physical science:

Did you link this to any of the NJ Standards? If so, which ones?
Technology design process, lab safety, mathematical representation (I believe they are 5.4, 5.1 & 5.2).
Yes, 5.1 5.3,5.7
The NJ standard for technology education fit this very nicely.
The technology standards of course applies but math, workplace readiness skills, physical science.
No, it tied in so well with the Forces Unit I put in under the same umbrella.
No, if I had taught this as a part of the science program I would have done so; however as an enrichment pilot program no written standards were requested other than the AWIM curriculum.

ANALYSIS AND USE OF PRE- AND POST-TESTS

The AWIM curriculum as written has several embedded assessments (including concept maps and gear-train drawings that are revisited), but it haD no pre-tests to measure misconceptions or post-tests to measure change. We therefore piloted one pre-test and two pre/post-tests. Since understanding gears is a fundamental component of the curriculum, the first pre-test was designed to help teachers assess student understanding of how a gear chain works. The pre-post tests were designed by the Boston Museum of Science to assess student understanding of what an engineer does and what technology is, and were also used in the EOFNJ elementary curriculum. Although all the teachers reported that they taught the engineering design process as part of the curriculum (see above), the curriculum did not directly teach an understanding of what an engineer does or what technology is. However, we wanted to see if it would change student perceptions of these two concepts, and also how the middle-school student results would compare with the elementary student results.

The first part of this section will analyze the results of each test; the second part will summarize how the teachers reported that they used them, and the third part will discuss how they might be used in the future.

Gears pre-test
(6th, 7th, and 8th grades)

The gears pre-test had three parts. Students were shown diagrams and asked to predict the direction of the final gear in a five-gear open-chain (O-C) configuration and the second gear in a five-gear close-chain (C-C) configuration. They were then asked to predict the direction of the final gear in a 414-gear long open-chain (L-C) configuration (with no diagram). The goal of the first diagram was for the students to figure out a general gear-chain rule (that the final gear in an odd numbered chain goes in the same direction as the first gear), while the second required that they apply the rule to a different situation (a closed chain), a counterintuitive application since the tendency is to think the first gear will "push" the second in the same direction. The final test requires that the student apply the open-chain rule to a word problem that has the opposite result from the first open-chain application (with an even-numbered chain, the final gear goes in the opposite direction from the first year).[1]

While almost 60 percent of the 6th-graders grasped the open-chain configuration, less than half were able to apply the concept to the long-chain and fewer still understood the closed-chain configuration. The 7th graders did best on all three tests, while the 8th graders were in the middle. This is probably the result of the students in the particular classes: the 7th-graders were all in an advanced class, while the 8th-graders included a number of special education students. Although the closed-chain configuration is the most difficult to conceptualize, the long-chain question was the most difficult for all but the 6th-graders, possibly because it was a word problem:

Grade	Percent correct		
	Open Chain (O-C)	**Closed Chain (C-C)**	**Long Chain (L-C)**
6th (n=44)	59%	36%	43%
7th (n=25)	84%	68%	56%
8th (n=136)	71%	61%	45%
Total	69%	56%	45%

There was a significant difference between grades on the O-C (p=.032, which is less than .05) and C-C (p=.003, which is less than .05) tests, but not on the L-C question (see ANOVA tables below). This confirms what is clear from the percentage table above—that the 8th-grade students were anomalous in having trouble with the L-C problem:

ANOVA Table

			Sum of Squares	df	Mean Square	F	Sig.
Open chain * Grade	Between Groups	(Combined)	1.316	2	.658	3.498	.032
	Within Groups		35.731	190	.188		
	Total		37.047	192			

[1] These tests were adapted from a much more complex study by Dan Schwartz and John Black on mental models of physical systems. See Daniel L. Schwartz and John B. Black, "Shuttling between Depictive Models and Abstract Rules," *Cognitive Science* 20, no. 4 (October-December 1996): 457-497.

Closed chain * Grade	Between Groups	(Combined)	2.663	2	1.331	5.856	.003
	Within Groups		42.516	187	.227		
	Total		45.179	189			
Long chain * Grade	Between Groups	(Combined)	.281	2	.140	.556	.574
	Within Groups		46.214	183	.253		
	Total		46.495	185			

"What is an engineer?" and "What is technology?" Pre- and post-test results

Since these two pre-post tests were designed for elementary school students who were engaged in a curriculum that directly addressed the topics of technology and engineering, while the AWIM curriculum only does so indirectly, we wanted explore the use of the tests to see:

1) If they would show overall change for middle-school students (they would not, for instance, if middle-school students got them all right on the pre-test).
2) If item analysis would reveal anything interesting about middle-school students' conceptions of engineering and technology
3) How the middle-school students' responses would differ from the elementary students' responses.
4) If these tests would be useful for the middle-school teachers (as diagnostics).

Students at all three grade levels had more difficulty with the engineering test than the technology test. At all grade levels and on both tests, the standard deviations were high, indicating a wide range of student responses within each level:

Percent correct on pre-test and post-test compared

		What is technology?		What is engineering?	
Grade		**Pre-test**	**Post-test**	**Pre-test**	**Post-test**
6	Mean	.6497	.6538	.3910	.4863
	N	43	39	43	41
	Std. Deviation	.17313	.18576	.12507	.18777
7	Mean	.7075	.7675	.5075	.5525

	N	25	25	25	25
	Std. Deviation	.21019	.20214	.15022	.15168
8	Mean	.7538	.8595	.4820	.6619
	N	132	117	132	117
	Std. Deviation	.21075	.17580	.19817	.19423
Total	**Mean**	**.7256**	**.8025**	**.4656**	**.6076**
	N	200	181	200	183
	Std. Deviation	.20665	.19930	.18297	.20113

However, as we shall show in the item-analysis below, we suspect that some of the difference between the two tests is because some of the engineering test items were ambiguous—even an adult might get them wrong. In addition, student performance on the "What is an engineer?" pre-test and on both post-tests varied by teacher, indicating that the composition of the class may have made a difference:

Percentage correct for pre- and post-tests

				Sum of Squares	df	Mean Square	F	Sig.
What is technology?	Pre-test * Teacher	Between Groups	(Combined)	.363	4	.091	2.178	.073
		Within Groups		8.135	195	.042		
		Total		8.498	199			
	Post-test * Teacher	Between Groups	(Combined)	1.812	4	.453	14.914	.000
		Within Groups		5.408	178	.030		
		Total		7.220	182			
What is an engineer?	Pre-test * Teacher	Between Groups	(Combined)	.342	4	.086	2.638	.035
		Within Groups		6.320	195	.032		
		Total		6.662	199			
	Post-test * Teacher	Between Groups	(Combined)	1.722	4	.431	13.653	.000
		Within Groups		5.708	181	.032		
		Total		7.431	185			

Despite these differences, the pre- and post-test results on both tests were highly correlated ($p<.001$). In other words, at the student level, a student who did well on one did well on all the others, and vice-versa:

Correlations for percentage correct on both pre- and post-tests

			Pre-test		Post-test	
			What is technology?	What is an engineer?	What is technology?	What is an engineer?
Pre-test	What is technology?	Pearson Correlation	1	.387(**)	.479(**)	.349(**)
		Sig. (2-tailed)		.000	.000	.000
		N	200	200	177	179
	What is an engineer?	Pearson Correlation	.387(**)	1	.331(**)	.344(**)
		Sig. (2-tailed)	.000		.000	.000
		N	200	200	177	179
Post-test	What is technology?'	Pearson Correlation	.479(**)	.331(**)	1	.590(**)
		Sig. (2-tailed)	.000	.000		.000
		N	177	177	183	180
	What is an engineer?	Pearson Correlation	.349(**)	.344(**)	.590(**)	1
		Sig. (2-tailed)	.000	.000	.000	
		N	179	179	180	186

** Correlation is significant at the 0.01 level (2-tailed).

The difference between grades was also statistically significant—in other words, the students in the higher grades did better than the students in the lower grades, indicating that the tests do distinguish between grade levels:

Differences between grades in percentage correct on pre- and post-tests

				Sum of Squares	df	Mean Square	F	Sig.
What is technology?	Pre-test * Grade	Between Groups	(Combined)	.361	2	.180	4.366	.014
		Within Groups		8.138	197	.041		
		Total		8.498	199			
	Post-test * Grade	Between Groups	(Combined)	1.273	2	.636	19.273	.000
		Within Groups		5.877	178	.033		
		Total		7.150	180			

What is an engineer?	Pre-test * Grade	Between Groups	(Combined)	.319	2	.159	4.950	.008
		Within Groups		6.343	197	.032		
		Total		6.662	199			
	Post-test * Grade	Between Groups	(Combined)	1.024	2	.512	14.537	.000
		Within Groups		6.339	180	.035		
		Total		7.362	182			

Item analysis
"What is an engineer?"

The engineering test had 16 pictures with captions and asked the students to circle the "kinds of work that engineers do for their jobs." There were nine correct choices:

- Improve bandages
- Develop better bubble gum
- Design ways to clean water
- Read about inventions
- Figure out how to track luggage
- Work as a team
- Create warmer kinds of jackets
- Design tunnels
- Write computer programs

The seven incorrect choices were:

- Construct buildings
- Drive machines
- Repair cars
- Install wiring
- Clean teeth
- Sell food
- Arrange flowers

An item-by-item analysis of the pre- and post-tests for the 6^{th-}, 7^{th-}, and 8^{th}-grade students showed that their ideas about the kinds of work that engineers do expanded somewhat between the pre- and post-test, but that some misconceptions remained. However, four of the misconceptions that persisted—that engineers “construct buildings,” “drive machines,” “repair cars,” and “install wiring”—are arguably not misconceptions, or at least not unreasonable misconceptions for a middle-school student (or an elementary school student, for whom these tests were designed, or even an adult), since the people who do these jobs are often referred to as engineers: people who work at construction sites are often called “construction engineers” and people who work at car-repair facilities are referred to as “automotive engineers,” while those who drive certain mechanical vehicles are also often called engineers (i.e., on subways).

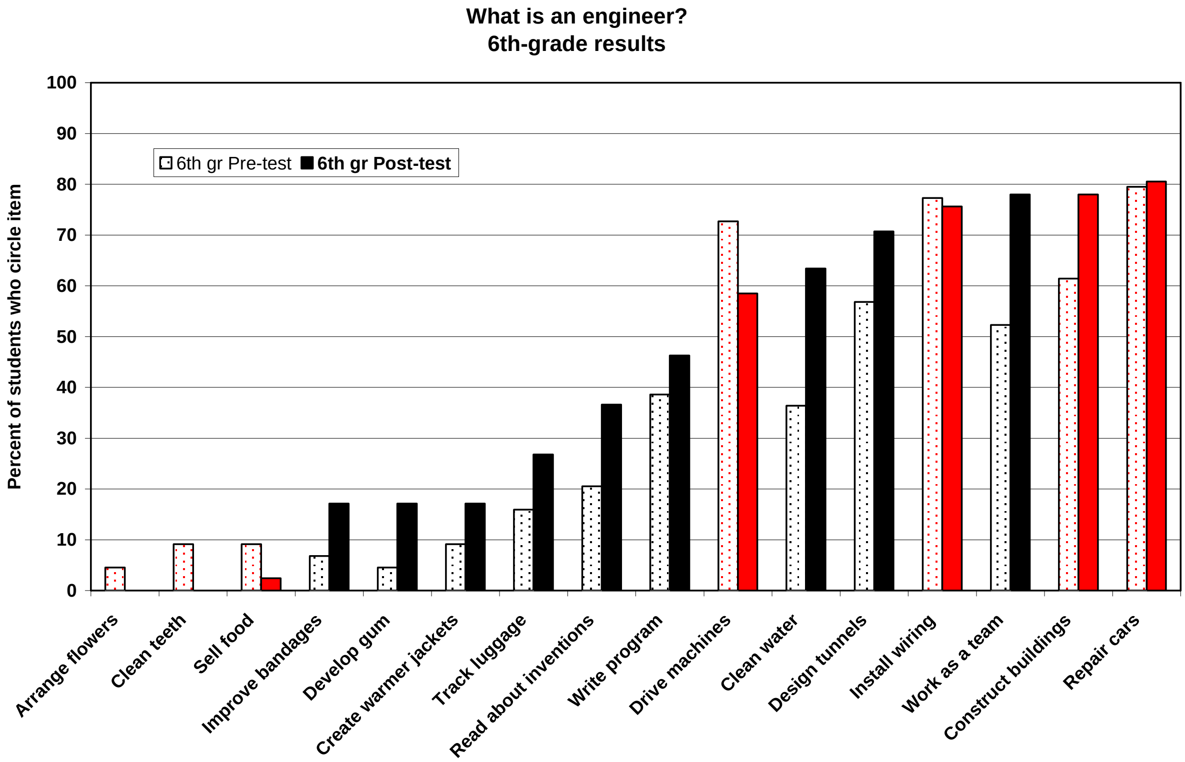
Here are the results by grade:

6th Grade

The chart below shows the change from pre-test to post-test for the sixth graders. The seven items that are considered incorrect are highlighted in red; the correct items are in black.

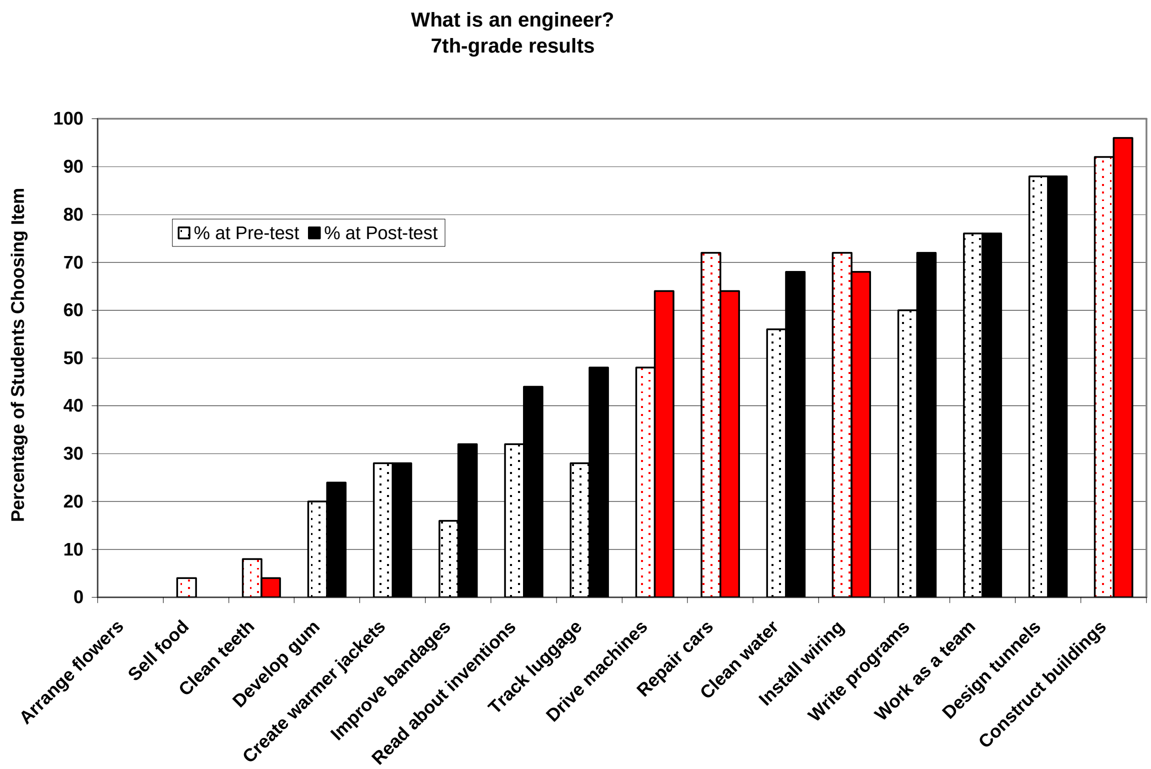
If we focus on the nine correct items, we find that in the pre-test, very few students consider some of the more subtle forms of engineering—those on the left-end of the chart, including developing gum, improving bandages, creating warmer jackets, tracking luggage, and reading about inventions—to be part of an engineer’s job and that although the percent choosing these items improved, it never reached more than half of all students. On the other hand, if we focus on those seven items that the test-designers considered not to be engineering, we see that four of them are were highly likely to be considered engineering by the students, and this changed very little from pre-post tests. This could indicate that these are firm misconceptions, but it could also be argued that they are not misconceptions at all, but valid interpretations of current language use.

However, the largest changes were in the middle and show that the students’ conception of what an engineer does broadened considerably between the two tests: almost twice as many students in the post-test correctly considered cleaning water to be engineering, while there were also large increases in the numbers who considered reading about inventions and working as a team to be engineering. These latter two are important because they seem likely to have arisen from having participated in the AWIM curriculum, which asks the students to copy elaborate diagrams and emphasizes teamwork.



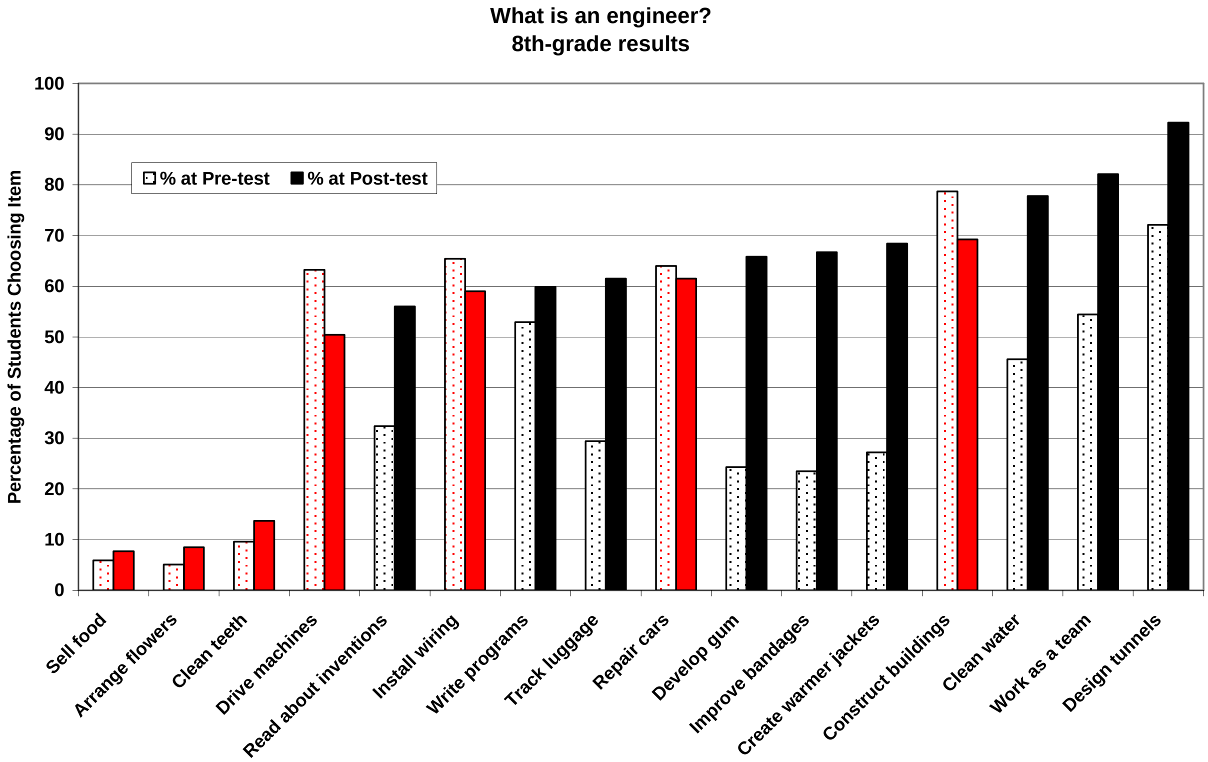
7th Grade

The 7th-graders followed a very similar pattern, although a slightly larger percentage were likely to consider the subtle tasks to be engineering, particularly by the post-test. But they had, and maintained, the same misconceptions. In fact, their conviction that constructing buildings was engineering strengthened, although their evaluation of repair cars was weaker. In addition, they did not change as much in the middle areas (cleaning water, working as a team), which they had already considered engineering at the pre-test:



8th Grade

In many ways, the 8th-graders began more like the 6th-graders than the 7th-graders but they differed in the huge post-test gain on some items. For instance, they were less likely than the 7th-graders to consider teamwork as part of engineering on the pre-test but were more likely to consider this part of engineering on the post-test. In addition, by post-test, the 8th-graders had greatly expanded their conception of what engineers to do to include improving improve bandages, develop gum, create warmer jackets, and tracking luggage. It seems likely that this was the result of the teachers using the test as part of their instruction:



The pre-post changes for all grades are summarized in the chart below, with the changes in the correct choices separated in the changes in the incorrect choices. The two largest changes at each grade level are highlighted in bold. Negative changes mean that more students incorrectly chose an item:

What is an engineer?
% change in incorrect responses at post-test
Post-test by Grade

Item	6th	7th	8th
Correct choices			
Clean water	**+29**	+12	+34
Work as team	**+27**	0	+29
Read about inventions	+20	+12	+29
Develop gum	+18	+4	**+46**
Improve bandages	+16	**+16**	+29
Track luggage	+16	**+20**	+37
Design tunnels	+15	0	+19

Create jackets	+13	0	**+45**
Write programs	+11	+12	+11
Incorrect choices			
Construct buildings	-10	-8	+22
Sell food	0	0	0
Clean teeth	+9	+4	-2
Install wiring	+9	+4	+17
Repair cars	+6	+8	+13
Arrange flowers	+5	0	-2
Drive machines	+20	+14	+22

While the pre-post tests tell us something about student conceptions/misconceptions, an open-ended question that asked student to write a sentence describing "What is an engineer?" enables us to explore some of these conceptions in more detail. The table below sorts the 10 most frequently used words that pertain to engineering, with those that declined in use in the top half of the chart and those that increased in use in the bottom half. Note that some students might use several of these words in one sentence, so the list does not correlate with the number of responses (91 for the pre-test and 97 for the post-test):

	Pre	**Post**
Decreased from pre- to post-test		
BUILD	28	21
SOLVE	14	8
MACHINE	13	2
REPAIR	6	2
ENTRIES THAT USED NONE THE 10 WORDS	18	5
Increased from pre- to post-test		
DESIGN	33	37
BETTER	8	29
IMPROVE	13	26
INVENT	11	13
CREATE	8	12
TEAM	3	5

This chart shows two types of change: first, many students simply became better able to answer the question, as the decreased in the number who used none of the 10 words shows (almost all of those who did not use any of the 10 words got less than 50 percent correct on the pre-test); and second, there was a marked shift from a focus on engineering working with machines to a to a broader definition that revolved around improving an object or making things better for the world. For instance, in the pre-test, students who used the term "design" frequently used it in sentences such as the following:

- "An engineer is someone who constructs and repairs mechanical things."
- "An engineer is someone who constructs buildings and drives machines."
- "An engineer is a person or people who designs things and does stuff with cars, machines, buildings, etc. That's what I think an engineer does."

In the post-test, there are fewer references to machines (including cars) and students were more likely to use the words "improve" and "better," as in "make things better":

- "An engineer is a person who develops or improves things."
- "Someone who works to improve things."
- "A person who designs things that can improve how we live."
- "An engineer is a person that improves things in order to create newer and better things."
- "An engineer is someone who designs ways to make things better."

It seems possible that this expanded definition may have in part the result of the students' exposure to the iterative design process during the curriculum.

"What is technology?"
Item analysis of the pre- and post-tests

As noted above, the students did better on the technology pre- and post-tests than on the engineering tests. Students at all grade levels improved on the post-tests, with the changes greater for older students, but once again, the standard deviations were high.

The technology test had 16 pictures with captions and asked the students to circle those items that "you think are technology." The twelve correct choices were as follows:

- Subway
- Cellular phone
- Television

- Factory
- Power lines
- Books
- Cup
- Bandage
- Shoes
- House
- Bicycle
- Bridge

There were only four incorrect choices:

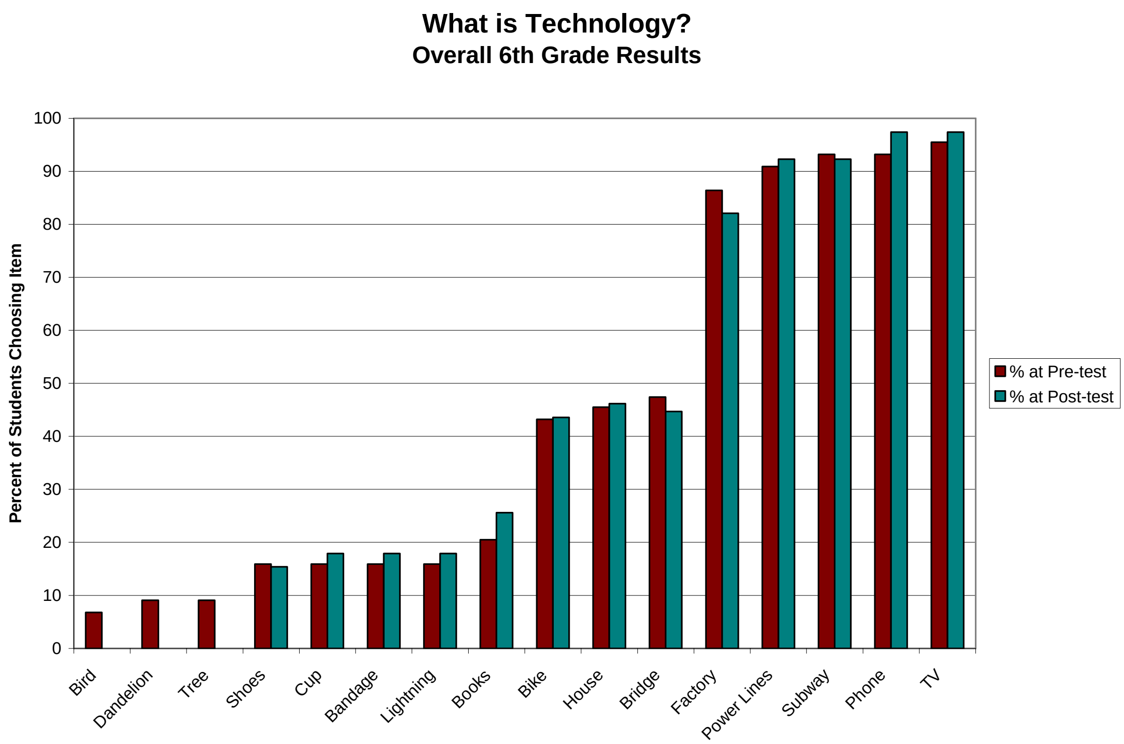
- Dandelions
- Oak tree
- Bird
- Lightning

For this test, then, both the choices and the wording of the prompt seem even more ambiguous than for the engineering test. First, when the items are lined up as above, the distinction between man-made and “natural” items is clearer than it is when you are faced with making a decision about which is which. Second, since only four items are not technology, it is possible that the students did better on this test than the engineering test simply by choosing at random. Third, although this was not a cause of student error, it is nevertheless true that technology is used in many so-called “natural” products, through genetic engineering. And fourth, the question itself (“What is technology?”) is unclear, since none of these *is* technology. The dictionary definition of technology describes it as an application of knowledge, a capability, or specialized aspects of a field. This is taken from the Merriam-Webster Online Dictionary:

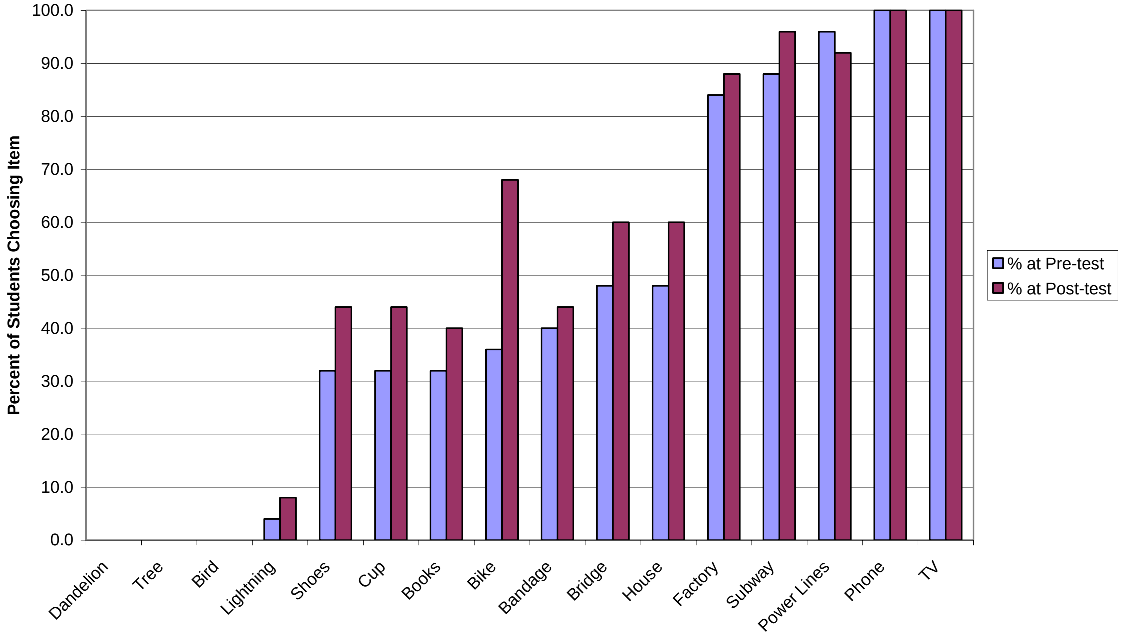
Technology: 1 a : the practical application of knowledge especially in a particular area **: ENGINEERING** 2 <medical *technology*> **b :** a capability given by the practical application of knowledge <a car's fuel-saving *technology*> **2 :** a manner of accomplishing a task especially using technical processes, methods, or knowledge <new *technologies* for information storage> **3 :** the specialized aspects of a particular field of endeavor <educational *technology*>

It is not clear how any of these would apply to shoes, a cup, bandages, books, or other of the “correct” items listed above.

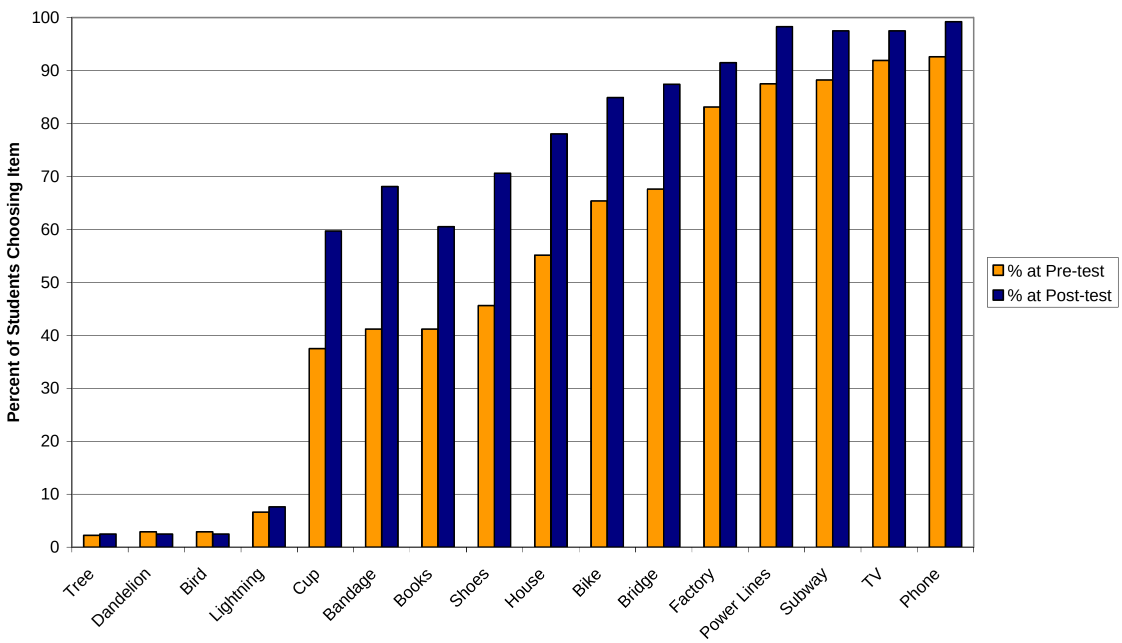
In fact, as the following three graphs show, the students at all grade levels considered TV, phones, subways, power lines, and factories to be technology, while a majority at all grades had trouble with the last seven “correct” items listed above. By post-test, the 8th-graders had an expanded their definition to include these items. As with the engineering test, the extent to which the 8th-graders got the correct answers again suggests their teachers taught the subject. Here are the three charts:



What is Technology?
Overall 7th Grade Results



What is Technology?
Overall 8th Grade Results



Here are the pre-test/post-test changes for the seven items, with the item with the greatest change at each grade level highlighted in bold:

"What is technology?"
Percent increase in correct responses at post-test by grade

Item	6th	7th	8th
Books	**+14**	+8	+23
Cup	+11	+12	+26
Bandage	+11	+4	**+30**
Shoes	+9	+12	+27
House	+7	+12	+24
Bicycle	+6	**+32**	+19
Bridge	+4	+12	+19

The students' pre-test responses to an open-ended question that asked "How do you know if something is technology?" explain why they all chose TVs, phones, subways, etc.: they narrowly associate technology with electrical power:

- "I know if something is technology because it is electrical."
- "Something that is technology is usually something that involves machine or electricity."
- "Something is technology if [it] runs by power or makes power for things to work and solve a problem."

The post-test answers to this question showed that they had expanded their understanding to include anything man-made:

- "Technology is anything made by humans, man-made."
- "Technology is inventions that are man made and are not naturally made like birds and trees. They improve lifestyles."
- "It is something that makes life easier for humans and is manmade."

However, those students who still failed to identify certain items (e.g., shoes) as technology at post-test continued to believe that technology was associated with power, particularly electricity:

- "You know something is technology when something is made up of electricity."
- "I know if it is technology if the thing has electricity running it or if it run by a force such as a bike."

- "If it uses some sort of power."

Teacher use of pre- and post-tests

The final survey for the teachers asked about their use of the pre- and post-tests discussed above, as well as of additional assessments embedded throughout the curriculum. The six teachers who had finished teaching the unit by June responded to this survey.

In general, they found most of the pre-tests and post-tests only somewhat useful, were split on the concept maps and student reflections (non-traditional assessments that some of the teachers might be less familiar with), and found the embedded assessments (in Units 2 and 3) the most useful:

How useful did you find the following pre/post tests and other assessments?

	Very	Somewhat	Not very	Not at all
Gears pre-test	1	**5**	0	0
What is an engineer pre-test	0	**5**	1	0
What is technology pre-test	0	**5**	1	0
What is an engineer post-test	0	**6**	0	0
What is technology post-test	0	**6**	0	0
Vocabulary check	1	**5**	0	0
Concept maps	3	2	1	0
Student reflections	3	3	0	0
Basic understanding of gears (in Unit 2)	**4**	2	0	0
Gear train drawings (in Unit 3)	**5**	0	1	0

All reported that they either marked or reviewed all of the tests for themselves, but only half or less (depending on the assessment) reported that they used them as a basis for class discussion. Again, they were more likely to do this for the embedded assessments in Units 2 and 3 than for the other tests:

How did you use the following pre/post tests and other assessments?
[You can check more than one choice in each row.]

	Marked and gave back to students	Marked for myself	Reviewed for myself	Used in class discussion
Gears pre-test	1	1	4	3
What is an engineer pre-test	1	1	4	2
What is technology pre-test	1	1	4	2

What is an engineer post-test	1	1	4	2
What is technology post-test	1	1	4	2
Vocabulary check	1	0	4	3
Concept maps	2	0	2	3
Student reflections	3	1	2	2
Basic understanding of gears (in Unit 2)	4	0	1	5
Gear train drawings (in Unit 3)	3	0	2	4

An open-ended question at the end of the Unit 1 survey asked for details about the three pre-tests (gears, What is an engineer? What is technology?). Some of the teachers used them to get a general sense of how much the students knew:

- "Yes, the pretests help me get a baseline as to where to start."
- "The students just took the test with no warm-up or input in order to establish their base level."
- "The pre-tests/surveys just gave me background in general and a baseline for the students. They didn't really impact my teaching mainly because the students all roughly were on the same level."
- "Yes, they set the tone for the 'big picture.'"
- "They weren't very helpful, but I did see how little my students know about these topics."

One teacher thought the engineering and technology pre-tests were useful as an introduction but another thought they were not:

- "The pre-tests were helpful because it introduced students to engineering and technology."
- "Not really, the 'What is technology?' and 'What is an engineer?' seemed to be designed for younger students. It didn't seem the topics covered in the pre-tests were ever discussed any further in any of the chosen activities (possibly need to complete entire unit with all disciplines)."

And one teacher, who wanted the focus on engineering, had an interesting comment on the gears assessment:

- "It built some excitement for the project, but it focused them on gears more than engineering. That also initially turned off some of my girls to the project --corrected since – 'this is a boy project.'"

Recommendations about the pre- and post-tests

Gears pre-test: It is clear that less than half the students at all grade levels knew how gears work, so the gears pre-test could be useful in helping teachers diagnose their understandings of gears. However, teachers need instructions on how to integrate this pre-test into the curriculum by teaching with the results.

What is an engineer? pre-post test: Although the engineering test did show a gradual expansion in understanding of what an engineer does, both over time and over the grade levels, it asks students to make some very fine distinctions between what is and what is not engineering, distinctions that we are not sure even an adult could (or should) make. If these were corrected, teachers might find this a useful pre-post test, particularly if prior knowledge of the results allow them to place their students' understanding on a continuum and if they then include discussions of engineering tasks in their curriculum.

What is technology? pre-post test: As for the technology test, it not only asks the students to make even more difficult distinctions, but it is not clear that considering anything man-made to be "technology" is a useful approach to the topic, or that "natural" products are not. Although teachers might find the answers to the open-ended questions useful in indicating how narrowly or broadly the students conceive of technology, there seem to be easier ways to do this.

Conclusion

One goal of the evaluation was to address a series of broad questions. These questions, with the assessment to date, are as follows:

Curriculum design and implementation

- Can the adapted and condensed AWIM curriculum be implemented successfully? Is it logical and coherent from a teaching point of view? Can it be implemented in the allotted time?

Answer: The curriculum, which was condensed by CIESE to fit into four weeks, was greeted with approval by all the teachers who have responded to the surveys. However, all reported that they either took more than the allotted time or had to cut some items in order to make it fit. So the timeframe needs to be reviewed.

- How do teachers implement the AWIM curriculum? Is there fidelity to the AWIM curriculum as written? Are the teachers able to manage the implementation on their own? What role(s) do the CIESE support team play?
  Answer: One of the strengths of the curriculum is that teachers can implement it in different ways. However, it does seem that some teachers did not fully implement the iterative design process, for instance by not revisiting the concept maps and gear-train drawings, and also did not fully implement the unit on presentations. Not spending time on the presentations was generally because of time constraints, but not spent time on the iterative aspects of the design process was more likely to be because the students settled on one design and stuck with it, or because it was difficult to get them to stop the trial-and-error part of designing to take notes. Expectations should be clarified here.

  Although the final survey did not ask about the CIESE support time, it appears to have been very important in giving the teachers the confidence to take on a new and complex curriculum, as well as in helping with various technical aspects.

- What additions do teachers feel they need to make to the AWIM curriculum in order to use it with their students? What other changes do they make and for what reasons? Answer: Overall, the teachers made very few changes and there was no particular pattern to the changes they did make.

- How familiar are teachers with the concepts covered in the AWIM curriculum? How many of them do they already teach? How does the AWIM curriculum fit with their existing school curricula? Does it replace parts of the syllabus, or is it an addition?
  Answer: None reported that they already teach all the concepts covered in the curriculum, but some reported that this was an excellent follow-up to the more basic material they already teach. All taught this as an addition to the existing syllabus, but one reason for that is that it was new material. If they were to teach it again, the

might integrate into what they already cover.

Student learning

- Does the AWIM curriculum increase student interest in physical science/engineering?
  Answer: We did not address this directly, but all the teachers reported that the students were enthusiastic about their projects.

- Do the students learn the concepts covered in the AWIM curriculum?
  Answer: Students who built the cars had to learn the concepts. However, since they worked in teams, it is not clear if they all learned the concepts and the pre-post tests did not help assess this. If there a key concepts that the curriculum is supposed to teach, then a better pre-post assessment needs to be developed.

- Are there gender differences in interest in the AWIM curriculum, final projects/designs, and pre-post assessments of learning?
  Answer: The fact that the curriculum combined many different skills in addition to building cars was a plus in attracting girls, who seem to have done most of the poster designing and car decorating. In addition, the teachers reported that, once an initial hesitation was overcome, the girls liked the construction process.