Spring 4: Performance assessment techniques.

Objectives:
Prepare teachers to analyze performance of individual students and student groups on design challenges. The teachers will be assessed in the Water Flow problem taught above the same way we want them to assess their own students.

PD Activities:
Having just experienced the Water Flow problem, and with curriculum adaptation coming up soon in the professional development schedule, it is important that teachers begin to understand what the different ways that they can assess students' abilities to apply engineering design, science, and mathematics. Teachers are taught the specific things to look for in a student's engineering solution and indicators found in his or her engineering notebook.

The mathematics teacher is going to assess for math achievement, the science teacher for science achievement, the technology teacher for engineering design. Each teacher is going to assess for the content standard relevant to his or her subject. For example, the math teacher might look at a students engineering design notebook, but she or he will more likely test the student for achievement on the related math skill.

Resources
International Technology Education Association (2004). *Measuring progress: A guide to assessing students for technological literacy*. Reston, VA: author.
International Technology Education Association (2000). *Standards for technological literacy: Content for the study of technology*. Reston, VA: author.

Professional Developer Input
The International Technology Education Association (ITEA) (2004) highlights important considerations when it comes to preparing for student assessment. Because the student's mastery of engineering design is a complex process requiring that multiple objectives be met, an engineering design assessment rubric is recommended as a primary means of measuring student achievement. Rubrics are an excellent way to let students know exactly what is expected of them when an assignment is made. Rubrics, once developed, provide an easy way to document student achievement on specific objectives.

Rubrics, if developed by the teacher prior to the design of a learning activity can provide an excellent guide to designing a learning activity, such as an engineering design challenge. You will learn in the Spring 6 professional development session that once objectives have been identified, the teacher should decide how the students' mastery of the objective can be recognized. These are student learning outcomes, and they must be observed and measured. Once the teacher has decided how mastery can be recognized, then he or she is in a position to design a rubric for assessment and then a learning activity.

First, in the left hand column, list the objectives that you identified that the student must know or be able to do. For all teachers, your state, province, or local school system provides curriculum guides of some variety in order to help you identify your students' learning objectives. For technology education teachers, learning objectives can be derived from the Standards for Technological Literacy: Content for the Study of Technology (ITEA, 2000).

One objective that you will have for your students is that they are able to apply the engineering design process. The first objective listed on the student assessment rubric below is "Followed the engineering design process." Perhaps it is time in your curriculum when students need to learn about transportation. Based on the standards for technological literacy, another objective that is included in the rubric below is "Describes transportation as a system." Perhaps when you finally design your learning activity, you will discover that there may be some prerequisite or enabling objectives that students need to learn simply to carry out the activity. In the rubric below, the teacher later, after designing the rubric, and then the activity, realized that students would need to understand some basic facts about fluid dynamics. That objective is represented in gray because the teacher added it after the fact.

Engineering Design Challenge Student Assessment Rubric

Objectives	Below Standard	At Standard	Above Standard	Specific Comments
Followed the engineering design process.	There were steps left out that turned out to be important.	There is evidence that the process was followed.	There is explicit evidence that the process was followed.	
Used mathematics to optimize, predict, describe solutions.	Used some but not all math applications to describe the solution.	Used all math applications to describe and optimize the solution.	Used all math applications to describe, predict, and optimize the solution.	
Worked within constraints and limitations.	One or more special accommodation had to be made in the laboratory to get the solution to work.	No special accommodation had to be made in the laboratory to get the solution to work.	The solution worked as close to a real-life implementation as feasible in the laboratory and the decision matrix was used to analyze alternative solutions.	
Satisfied specifications and parameters.	None of the quantifiable specifications were met by the solution.	Some of the quantifiable specifications were met by the solution.	All of the quantifiable specifications were met by the solution.	
Describes transportation as a system.	The student cannot describe the water system in the terms used to describe any transportation system.	The student can describe the water system in the terms used to describe any transportation system.	The student can describe the water system in the terms used to describe any transportation system, and this is evident in the portfolio.	
Fully documented the process in the portfolio.	The portfolio reflects the general engineering design process.	The portfolio provides evidence of understanding for the objectives stated above.	The portfolio documents the specific design process used to solve this problem.	
Applied understanding of fluid mechanics.	There is little evidence that the understanding of fluid mechanics is represented in the solution.	It is evident that the understanding of fluid mechanics is represented in the solution.	It is evident that the understanding of fluid mechanics is represented in the solution and this is explicitly documented in the portfolio.	

Comments:

Next, you need to identify an acceptable level of performance. In the rubric above, At Standard represents what is acceptable to the teacher regarding each objective. Then describe the other levels of performance; Below Standard and Above Standard. While it may not be possible try to avoid inconsistencies in describing the levels of performance for the different objectives. For example, in one objective if you specify quantity and in another objective, the main criterion is quality, then you are tending to be inconsistent.

Outcomes:
Assessment rubrics

Success Indicators:
Participants self-report satisfaction with the PD instruction on assessment, Rubrics are developed to meet the assessment development criteria.

Spring 5: Instructional design and adaptation.

Objectives:
Examine and critique curriculum and instructional materials for infusing design into standards-based STEM instruction; Propose motivating lessons for STEM classrooms, Use instructional design to plan lessons that infuse engineering design.

PD Activities:
Teachers will engage in instructional design to infuse engineering design into instruction into technology, science, and mathematics. They will learn to develop student materials and other resources needed to successfully teach an engineering design challenge to their students.

Teachers are given an assignment, such as “what would you do to infuse engineering design for competency X in your curriculum?” (A simple assignment much like the Bungee Cord problem or the Food for the World may be identified.)

- Given criteria on what makes an engineering design idea feasible, teachers investigate the feasibility of implementing the activities teachers have identified respectively.
- Teachers discuss the feasibility of implementing the activities with the professional development providers and other teachers and possibly their administrators.
- Teachers and providers identify where else in the existing curriculum each teacher can infuse engineering design. Teachers start practicing infusing engineering design into existing activities.

General Curriculum Resources of Possible Interest to All Participants

Altec (2007). *Rubistar: Create rubrics for your project-based learning activities*. Lawrence, KS: University of Kansas. Retrieved January 16, 2008 from: http://www.greenriver.edu/LearningOutcomes/Documents/Rubric_Development_Toolbox.doc

American Association for the Advancement of Science (1993). *Benchmarks for science literacy.* New York: Oxford University Press. Retrieved June 25, 2005 from: http://www.project2061.org/tools/benchol/bolintro.htm

Anderson, L. W., & Krathwohl, D. R. (Eds.), Airasian, P. W., Cruikshank, K. A., Mayer, R. E., Pintrich, P. R., Raths, J., & Wittrock, M. C. (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's Taxonomy of Educational Objectives.* New York: Addison Wesley Longman.

Bloom, B. S., (Ed.), Englehart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). *Taxonomy of educational objectives: The classification of educational goals.* New York: David McKay Company.

Commission on Standards for School Mathematics (2000). *Curriculum and evaluation standards for school mathematics* [online]. Reston, VA: National Council of Teachers of Mathematics. Retrieved June 25, 2005 from: http://www.nctm.org/standards/

Frye, E. (1997). *Engineering problem solving for mathematics, science, and technology education*. Hanover, NH: Trustees of Dartmouth College. Retrieved January 16, 2008 from: http://thayer.dartmouth.edu/teps/book.html

International Technology Education Association (2004). *Measuring progress: A guide to assessing students for technological literacy.* Reston, VA: author.

International Technology Education Association (2000). *Standards for technological literacy: Content for the study of technology.* Reston, VA: author. Retrieved January 16, 2008 from: http://www.iteaconnect.org/TAA/PDFs/xstnd.pdf

Jacobs, H. H. (1999). Introduction. In R. Fogarty (Ed.) *The mindful school: How to integrate the curriculum* (pp. xi–xv). Palintine, IL: Skylight.

LaPorte, J. E., & Sanders, M. E. (1996). *Technology, science, mathematics connection activitities*: *A teacher's resource binder*. Peoria, IL: Glencoe/McGraw-Hill.

Mid-Continent Research for Education and Learning (2004). *Content knowledge (fourth edition):* A compilation of content standards for K-12 curriculum in both searchable and browseable formats. Aurora, CO: author. Retrieved June 25, 2005 from: http://www.mcrel.org/standards-benchmarks/

National Research Council (1996). *National science education standards* [online]. Washington: National Academy Press. Retrieved June 25, 2005 from: http://bob.nap.edu/html/nses/

Teach Engineering (2008). *Resources for k – 12.* Boulder, CO: author. Retrieved January 16, 2008 from: http://www.teachengineering.com/index.php

Wiggins, G., & McTighe, J. (1998). *Understanding by design.* Alexandria, VA: Association for Supervision and Curriculum Development.

Wiggins, G., & McTighe, J. (2004). *Understanding by design: Professional development workbook.* Alexandria, VA: Association for Supervision and Curriculum Development.

Mathematics Curriculum Resources

North Carolina Department of Public Instruction (2003). *Standard course of study: Algebra I*. Raleigh, North Carolina: author. Retrieved January 16, 2008 from: http://www.ncpublicschools.org/curriculum/mathematics/scos/2003/9-12/45algebra1

North Carolina Department of Public Instruction (2003). *Standard course of study: Geometry*. Raleigh, North Carolina: author. Retrieved January 16, 2008 from: http://www.ncpublicschools.org/curriculum/mathematics/scos/2003/9-12/47geometry

North Carolina Department of Public Instruction (2003). *Standard course of study: Algebra II*. Raleigh, North Carolina: author. Retrieved January 16, 2008 from: http://www.ncpublicschools.org/curriculum/mathematics/scos/2003/9-12/49algebra2

North Carolina Department of Public Instruction (2003). *Standard course of study: Pre calculus*. Raleigh, North Carolina: author. Retrieved January 16, 2008 from: http://www.ncpublicschools.org/curriculum/mathematics/scos/2003/9-12/60precalculus

North Carolina Department of Public Instruction (2003). *Standard course of study: Grade 8*. Raleigh, North Carolina: author. Retrieved January 16, 2008 from: http://www.ncpublicschools.org/curriculum/mathematics/scos/2003/k-8/38grade8

Science Curriculum Resources

North Carolina Department of Public Instruction (2004). *Standard course of study: Biology*. Raleigh, North Carolina: author. Retrieved January 16, 2008 from: http://www.ncpublicschools.org/curriculum/science/scos/2004/23biology

North Carolina Department of Public Instruction (2004). *Standard course of study: Chemistry*. Raleigh, North Carolina: author. Retrieved January 16, 2008 from: http://www.ncpublicschools.org/curriculum/science/scos/2004/24chemistry

North Carolina Department of Public Instruction (2004). *Standard course of study: Earth/environmental science*. Raleigh, North Carolina: author. Retrieved January 16, 2008 from: http://www.ncpublicschools.org/curriculum/science/scos/2004/25earth

North Carolina Department of Public Instruction (2004). *Standard course of study: Physical science*. Raleigh, North Carolina: author. Retrieved January 16, 2008 from: http://www.ncpublicschools.org/curriculum/science/scos/2004/26physical

North Carolina Department of Public Instruction (2004). *Standard course of study: Physics*. Raleigh, North Carolina: author. Retrieved January 16, 2008 from: http://www.ncpublicschools.org/curriculum/science/scos/2004/27physics

Technology and Engineering Curriculum Resources

North Carolina Department of Public Instruction (2002). *Standard course of study: Fundamentals of technology*. Raleigh, North Carolina: author. Retrieved January 16, 2008 from: http://www.dpi.state.nc.us/cte/technology/course-descriptions.html#8110

North Carolina Department of Public Instruction (1997). *Standard course of study: Manufacturing systems*. Raleigh, North Carolina: author. Retrieved January 16, 2008 from: http://www.dpi.state.nc.us/cte/technology/course-descriptions.html#8115

North Carolina Department of Public Instruction (2004). *Standard course of study: Communication systems*. Raleigh, North Carolina: author. Retrieved January 16, 2008 from: http://www.dpi.state.nc.us/cte/technology/course-descriptions.html#8125

North Carolina Department of Public Instruction (2004). *Standard course of study: Structural systems*. Raleigh, North Carolina: author. Retrieved January 16, 2008 from: http://www.dpi.state.nc.us/cte/technology/course-descriptions.html#8141

North Carolina Department of Public Instruction (1998). *Standard course of study: Transportation systems*. Raleigh, North Carolina: author. Retrieved January 16, 2008 from: http://www.dpi.state.nc.us/cte/technology/course-descriptions.html#8126

Professional Developer Input

Feasibility Criteria for Infusing Engineering Design

In order for an existing activity or a new activity to be deemed feasible for infusing engineering design into it, in some capacity, it should possess *one* or more of the following features.

- The problem may be solved through some technological means.
- Either part or all of the engineering design process can be used, **but for your first try let's try to adapt an activity or curriculum objective that will use the whole engineering design process.**
- Mathematics and science are necessary in some form in the front end of the activity in order to inform the design prior to prototyping.
- The activity does not simply depend on mathematics or science at the end for testing prototypes.

For example, one professional development participant was teaching students about pin-hole cameras in his Communication Systems (technology education) class. It was not appropriate at the time of the lesson to have students participate in the entire engineering design process in order to develop their own pin-hole cameras. However, the teacher did teach students how to *optimize* their designs using mathematics. This partial integration of engineering design enhanced the learning process, but the engineering design process was not fully implemented. There is nothing wrong with this approach because it served the needs of the students, teacher, and curriculum. Instructional behavior was changed for the better.

In order for an existing activity or a new activity to be deemed feasible for infusing engineering design in the form of a fully developed engineering design challenge, it should possess *all* of the following features.

- The problem may be solved through some technological means.
- All of the engineering design process will be used.

- Mathematics and science are necessary in some form in the front end of the activity in order to inform the design prior to prototyping.
- The activity does not simply depend on mathematics or science at the end for testing prototypes.

For example, another professional development participant used engineering design notebooks and had her students go through all of the steps needed to fully experience the entire engineering design process. They developed catapults. She differentiated the levels of mathematics used to optimize and analyze designs based on student mathematical ability. Students experienced what it is like to do engineering design. Instructional behavior was changed for the better.

Identifying Sources for Activity Ideas

Of those resources identified above, in addition to your own curriculum guides, the most useful in terms of indentifying activities suitable for idea development related to infusing engineering design are those that are listed again below.

Frye, E. (1997). *Engineering problem solving for mathematics, science, and technology education*. Hanover, NH: Trustees of Dartmouth College. Retrieved January 16, 2008 from: http://thayer.dartmouth.edu/teps/book.html

LaPorte, J. E., & Sanders, M. E. (1996). *Technology, science, mathematics connection activitities*: *A teacher's resource binder*. Peoria, IL: Glencoe/McGraw-Hill.

Mid-Continent Research for Education and Learning (2004). *Content knowledge (fourth edition):* A compilation of content standards for K-12 curriculum in both searchable and browseable formats. Aurora, CO: author. Retrieved June 25, 2005 from: http://www.mcrel.org/standards-benchmarks/

Teach Engineering (2008). *Resources for k – 12.* Boulder, CO: author. Retrieved January 16, 2008 from: http://www.teachengineering.com/index.php

Standards

Any instructional development effort begins with content standards. Content forms the backbone of what and how students are to be taught. This is important in order to avoid the "shoot, aim, ready" effect that can sometimes happen when instruction is designed in a haphazard fashion. There are many standards organizations with resources available. For technology teachers and engineering teachers, the International Technology Education Association (2000) has developed the *Standards for Technological Literacy: Content for the Study of Technology.* The National Research Council (1996) developed national standards for science. And the Commission on Standards for School Mathematics (2000) of the National Council of Teachers of Mathematics developed national standards for mathematics. Most every state and province has some form of standards adapted and adopted in order to specify the content that school children must learn. Technology, engineering, science, and mathematics teachers need to take the time required to become familiar with those standards that will pertain to their teaching assignments.

Technology standards. For example, the following standard and benchmark from the *Standards for Technological Literacy* (ITEA,2000) are important for the technology education teacher's curriculum.

Standard: "Students will develop an understanding of engineering design" (p. 99).
Benchmark: "L. The process of engineering design takes into account a number of factors. These factors include safety, reliability, economic considerations, quality control, environmental concerns, manufacturability…" (p. 105).

The technology teacher in, say, North Carolina may also have other standards that students must achieve based on the curriculum guide used for his or her course. If the teacher were teaching *Fundamentals of Technology*, a North Carolina (2002) state standard course of study, then the following might be an important standard.

> Describe how the design process relates to technology and other disciplines
>
> The following outline characterizes what should be taught under Objective 5.02
> - Explain how design is related to technology, such as safety, functionality, and economy
> - Describe design processes related to various technological fields. (p. 213)

In this case, the state curriculum standard is virtually the same as the national standard. For this standard, the technology teacher can simply use the state standard.

What if there is not overlap with the important national standard? What if the teacher needed to teach the national standard above and the following state standard?

"Utilize a computer as an information management tool" (North Carolina Department of Public Instruction, 2002, p. 166).

When one thinks about it engineering design requires a number of processes. One of those processes that has already been taught is the analysis that is used to compare potential problem solutions, the Decision Matrix. The technology teacher, in order to determine whether or not a student used a decision matrix, would want to see the student's actual decision matrix in the student's engineering design notebook. That process requires the use of basic mathematics.

Computers are excellent at processing mathematical operations. Spreadsheets are used in this process. For a technology teacher to be confident that a student is able to utilize a computer as an information management tool, he or she would want to see the student's computer file in which the student manipulated data to create various statistics.

It is plausible that both the national engineering standard and the local information management standard could be taught in the same lesson. However, we will have to wait and see if this will be possible until after we follow an instructional design process that we will learn late in this session.

Mathematics standards. Perhaps the mathematics teacher has some students who are behind at the ninth grade level and needs to teach the following standard.

"The learner will understand and compute with real numbers" (North Carolina Department of Public Instruction, 2003, n.p.).

To be confident that the student is effectively doing computation, the mathematics teacher will want to see the student doing computations correctly.

It may be possible that when a student works with the Decision Matrix that the mathematics teacher will be able to collect evidence regarding computation.

Science standards. Perhaps the physical science teacher needs to teach the following standard.

"Competency Goal 3: The learner will analyze energy and its conservation.
3.01 Investigate and analyze storage of energy:

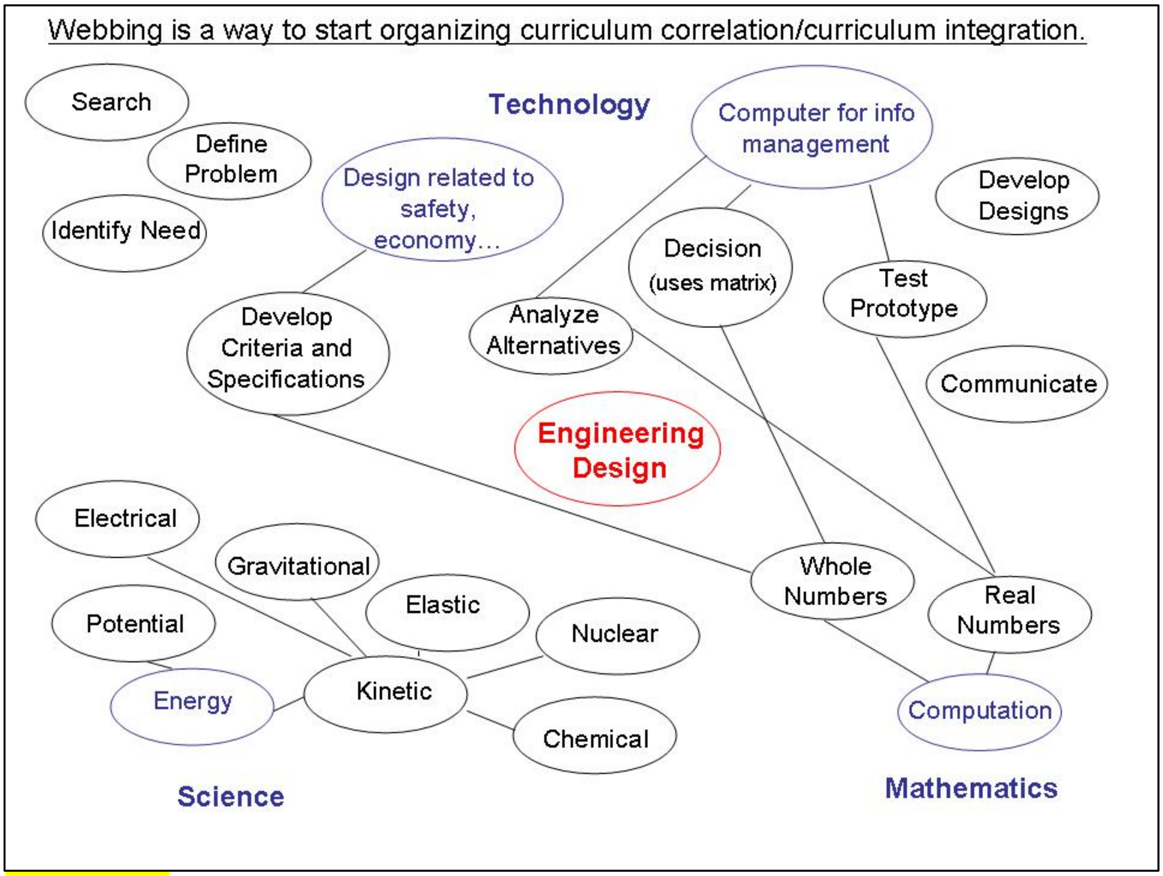
- Kinetic energy.
- Potential energies: gravitational, chemical, electrical, elastic, nuclear.
- Thermal energy." (North Carolina Department of Public Instruction, 2004, n.p.).

To be confident that the student is effectively investigating and analyzing energy, the science teacher must see the student manipulating energy in the laboratory.

However, it is not possible at this point in this session to determine how that laboratory activity will take place.

Curriculum Integration

What may already be coming to mind is that all three of these teachers, the technology, science, and mathematics teachers, may have some overlapping content. They can use a thematic or problem based approach to teach this overlapping content in a coordinated way. They could use curriculum correlation to deliver an integrated unit to their students (Jacobs, 1999). Webbing is a way for the three teachers to conduct a cursory cross reference of the various content standards that they need to teach. *This should be done without biasing thought as to what activities should take place*. It is simply a way to match content that needs to be taught by each teacher that appears to have commonality across the three subject areas. The figure below shows where three teachers developed a



content web. Notice that they knew that they wanted to be involved in addressing engineering design.

In the following example of curriculum integration planning, the technology education teacher or engineering teacher has already taught students about the basic engineering design process and some concepts related to engineering as a career. Current student understandings would include:

- *Students will be able to explain that engineering design is complex.*
- *Engineering design proceeds in a cycle.*
- *Designed solutions must use mathematics to optimize designs.*
- *Designed solutions must use applications of science in order to inform designs.*

The technology teacher needs to cover the fact that “The process of engineering design takes into account a number of factors. These factors include safety, reliability, economic considerations, quality control, environmental concerns, manufacturability…” (ITEA, 2000, p. 105). Technology class also needs to cover using the “computer as an information management tool.” The mathematics teacher knows that computation with real numbers (continuous quantities) needs to be reinforced with the ninth graders. The science teacher knows that energy needs to be covered. Because the technology teacher knows that the engineering design process will be taught, he or she has gone ahead and written down the related concepts. Immediately, it is noticed by the mathematics and technology teachers that there is overlapping content. Computation of real numbers will likely be able to be taught when students are analyzing solutions and testing prototypes. Computation of whole numbers may be used when students use the computer for information management. While he or she is not necessarily jumping ahead in the instructional design process, it is fairly obvious that computer spreadsheets would be a good way to work a decision matrix.

Notice, however, that the science teacher is not yet sure what the relationship is between what he or she needs to get taught and the technology and mathematics concepts.

Drawing in lines that connect the desired science content to other technology and mathematics content can come later after the instructional design process is followed.

Instructional Design

The important thing about instructional design is not to put the “cart before the horse.” Too often technology and engineering teachers have a favorite activity that they intend to teach but they fail to address specifically needed content standards when delivering instruction. Briefly stated, a better approach is to:

1. Identify the standard/objective/content item to be taught to students.
2. Decide how the teacher will know (evidence) that the student has achieved the objective.
3. Then design the instructional activity (Wiggins & McTighe, 1998).

Wiggins and McTighe refer to these as Stages 1 through 3.

Stage 1

Instead of thinking like an activity designer, think diagnostically.
“What is the most important objective needed to be taught?”
“How can I determine that my students understand the objectives?”
“How can I tell the difference between a student who comprehends and a student who does not comprehend?”
“What are the specific criteria for assessing a student on a specific objective?”

Bloom’s Taxonomy of Educational Objectives. Objectives can be written to specify a specific level of achievement. Bloom, et al, (1956) conceive of student achievement happening in a progression of levels from lower to higher. They also developed domains in which to cluster types of achievement. Hands-on, manipulative skills are categorized in the psychomotor domain, attitudes are categorized in the affective domain, and mental insights about constructs and concepts are categorized in the cognitive domain. Within the cognitive domain, Bloom, et al, conceive that students progress from one level of achievement to the next in the following sequence:

Knowledge – a student can *recall* a concept.
Comprehension – a student can *explain* a concept or construct.
Application – a student can *use* knowledge and comprehension of concepts or constructs in a situation that is different than the situation in which the construct or concept was originally learned.
Analysis – *breaking* a concept or construct into smaller parts.
Synthesis – *combining* concepts or constructs into a whole.
Evaluation – being knowledgeable enough to *judge* the correctness or value of a construct or concept.

Anderson, et al, (2001) developed a revision to Bloom's taxonomy for the cognitive domain. They classified the levels of cognitive achievement in the following sequence: remember, understand, apply, analyze, evaluate, and create. Nevertheless, the theory is that a student would need to be able to recall and be able to explain something before he or she can apply it. Theoretically, a student would need to be able to analyze and synthesize before being able to evaluate something.

"What is the most important objective needed to be taught?" When you choose a standard related to the cognitive domain from one of the national standards bodies, it will not likely be written in the form of an objective. Instead, it will simply identify a construct or concept that students need to achieve. It may be up to the teacher to develop a learning objective related to the standard.

Using key words from Bloom's Taxonomy of Educational Objectives may be useful in specifying the extent/level to which you want your students to learn the content standard. For example, the following objective from the technology education curriculum already has a key word added to it.

> "*Explain* how design is related to technology, such as safety, functionality, and economy" (North Carolina Department of Public Instruction, 2000, p. 213).

The word "explain" implies that the teacher is to make sure that the student comprehends that various factors influence the engineering design process.

Another objective that we considered follows.

> "*Utilize* a computer as an information management tool" (North Carolina Department of Public Instruction, 2002, p. 166).

The word “utilize” implies that the student will need to learn at the application level in terms of the cognitive domain-related learning involved. It is fairly obvious that if you decide to cover this objective by teaching students to use spreadsheets, then you will have to provide prerequisite instruction into things like the parts of the spreadsheet (cells, rows, columns…), how to enter data, how to duplicate data, what a function is, how to insert a function, etc. These prerequisites could be written as “enabling” objectives. They are referred to as enabling because you need to achieve them before achieving the more important objective. For example, an enabling objective could be for this example, “Students will be able to *identify* the parts of a spreadsheet when prompted to do so.” The most important objective is “Utilize a computer as an information management tool” (North Carolina Department of Public Instruction, 2002, p. 166). It could be referred to as the terminal objective. Often teachers become so preoccupied with teaching enabling objectives that they lose sight of the terminal objective.

Many teachers use Essential Questions to communicate objectives to students. The following could be useful essential questions to communicate our sample objectives from above.
What are the two basic ways of organizing a spreadsheet?
What is a cell?
What is a function?
Where does the answer to a function appear in a spreadsheet?

When is it useful to use a spreadsheet during the engineering design process?
How does the use of a computer spreadsheet represent information management?

Documenting Stage 1
In the following example of instructional design, the technology education teacher or engineering teacher has already taught students about the basic engineering design process and some concepts related to engineering as a career. Current student understandings would include:

- *Students will be able to explain that engineering design is complex.*
- *Engineering design proceeds in a cycle.*
- *Designed solutions must use mathematics to optimize designs.*
- *Designed solutions must use applications of science in order to inform designs.*

Wiggins and McTighe (1998, 2004) have a systematic process for documenting the instructional design process. For Stage 1, the technology education teacher or engineering teacher would write the following:

Objectives:

> *“Explain how design is related to technology, such as safety, functionality, and economy” (North Carolina Department of Public Instruction, 2000, p. 213).*
>
> *“Utilize a computer as an information management tool” (North Carolina Department of Public Instruction, 2002, p. 166).*

Understandings:

- *The engineer has to take many things into consideration when coming up with a designed solution to a problem.*
- *These considerations are also known as criteria, specifications, and constraints.*
- *Designed solutions must consider cost or economic effects.*
- *Designed solutions must consider available and unavailable technology.*
- *Designed solutions must consider the impacts on society and the environment.*

- *Students will be able to use computer based spreadsheets to manage the decision making process in engineering design.*
- *They must be able to use functions to use real numbers to determine the effectiveness of a design during optimization, testing, and analysis.*

Essential Questions:

- *What are some of the things that influence an engineer's designed solution to a problem?*
- *What is the engineering design process? Why is it like a cycle?*
- *What is a cell? What is the basic way that a spreadsheet is organized? What is a function?*
- *How can a computer be used to manage the engineering design process?*

The mathematics and science teachers should do the same form of documentation as it relates to what needs to be taught in their respective curricula.

Now that you more truly realize what needs to be taught, you can proceed with the next instructional design question listed above. It begins Stage 2 of the process.

Stage 2

"How can I determine that my students understand the objectives?" How do you know when a student has achieved an objective? You have to describe what the objective means. For the objective, "Utilize a computer as an information management tool" (North Carolina Department of Public Instruction, 2002, p. 166), you will need to observe some form of evidence that the student applied knowledge about spreadsheets while using the spreadsheet software loaded on a computer. List out specific things that would convince you that the student is correct.

Entered data into columns.
Inserted a function into a specific cell.
Calculation is correct.

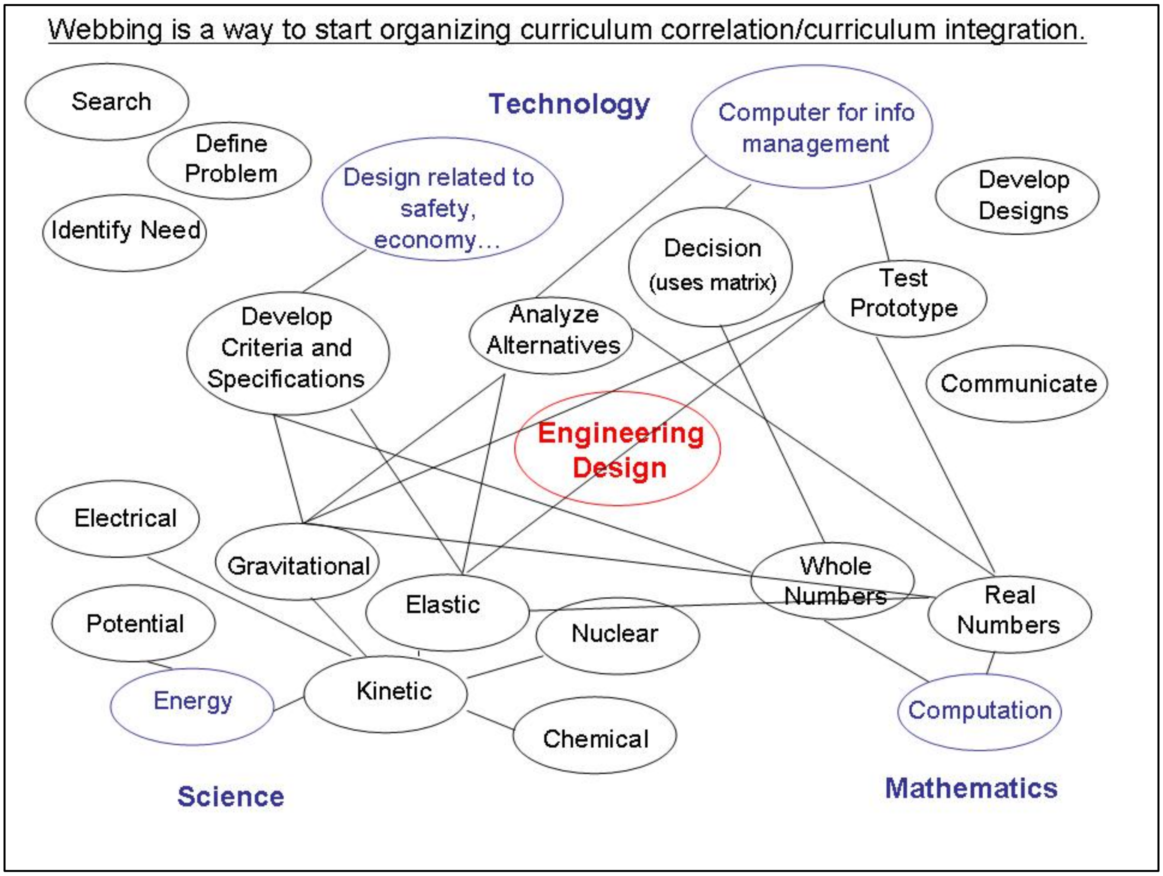
"How can I tell the difference between a student who comprehends and a student who does not comprehend?" At this point, it becomes obvious that the student will need to be prompted by a worksheet of some variety to "enter data into a column," because if he or she enters it in a row, it becomes obvious that the student does not *know* what a column on a spreadsheet is. Go ahead and start an assessment rubric like we learned above. What would be a failing performance? What would be a passing performance? What would be above passing?

"What are the specific criteria for assessing a student on a specific objective?" The terminal objective indicated an application level of achievement would be needed. To teach the prerequisite, enabling objectives, you will likely use direct instruction, demonstrate how to use a spreadsheet, and then immediately have students try out using the spreadsheet based on instructions from a handout. However, if they succeed at that, it is not necessarily application. The next thing is to have them use their skills and knowledge of spreadsheets to solve some *other* problem. Since you intend to teach engineering design, you will want to see if it can be incorporated into an engineering design problem.

Now that teachers understand exactly what to teach and how to assess the students, they can decide on what the activity will be. These teachers are going to do a Bungee Cord engineering design challenge.

The teachers can now finish their webbing development for the purpose of curriculum integration.

Having decided what the activity will be, the science teacher can now decide what concepts overlap with the mathematics and technology. You can see the lines that now connect the science concepts with the others in the diagram below.



Documenting Stage 2

Wiggins and McTighe (1998, 2004) have a systematic process for documenting what was determined for Stage 2. For Stage 2, the technology education teacher or engineering teacher would write the following:

Performance Task:

- *Given an engineering design notebook, the engineering design process, instruction on the ways that mathematics and science are applied to the engineering design process, the student will solve and engineering design problem. Each step in the design process will be documented in the engineering design notebook. The student will show where a spreadsheet was used to optimize solutions, to test and analyze solutions, and to make decisions regarding the specifications and criteria for the alternative solutions.*

- *Given a spreadsheet, the student will enter data and functions to determine decisions, optimizations, and analyses related to the engineering design problem. Spreadsheets will be organized by column. Spreadsheets will have functions inserted in logical locations. It will be obvious that the spreadsheet was used to manage the engineering design problem.*

Key Criteria:

- *It is evident in the engineering design notebook that various considerations were taken into account regarding the design's effects on costs, safety, ease of production, the environment, society, etc.*
- *Entered data in columns. Functions were inserted at the specified cells. Calculations were correct.*
- *Used the spreadsheet as part of the engineering design process. The student correctly applied what was learned in the spreadsheet assignment to the engineering design process for making decisions with the decision matrix and to the analysis of prototypes.*

You can break that down on the chart that you start for your rubric.

Objective	Below Standard	At Standard	Above Standard
***Explain* how design is related to other things such as safety, economy, functionality, society, the environment…**	There is no evidence that: criteria for judging the success of a design were determined, specifications were determined, analyses were made about the solutions performance.	There is evidence that some of the following was completed: criteria for judging the success of a design were determined, specifications were determined, analyses were made about the solutions performance.	There is evidence that all of the following were completed: criteria for judging the success of a design were determined, specifications were determined, analyses were made about the solutions performance.
***Use* a computer as an information management tool.**	Entered data in rows. Functions were not inserted in the specified cells. Calculations were not correct.	Entered data in columns. Functions were inserted at the specified cells. Calculations were correct. Used the spreadsheet as part of the engineering design process.	The student correctly *applied* what was learned in the spreadsheet assignment to the engineering design process for making decisions with the decision matrix and to the analysis of prototypes.

Other Evidence:
The actual artifacts that the students produce.

The mathematics and science teachers should do the same form of documentation as it relates to what needs to be taught in their respective curricula.

Now that you know how to evaluate your students, you can proceed to the next stage, Stage 3.

Stage 3
Designing the instructional plan. Wiggins and McTighe (1998, 2004) refer to Stage 3 as developing the learning plan. The learning plan explains what will happen in class in chronological order. What are the instructions that will be delivered? What will the learning activities be that involve students? Wiggins and McTighe basically advise the teacher to motivate the students to learn, including helping them to understand why the topic being taught is important for students to know or be able to do. They call for the teacher to provide prerequisite instruction, which may be in the form of direct instruction.

Wiggins and McTighe call for the teacher to engage the student in activities that will allow them to learn and work with/practice and master the main objectives, and they encourage the teacher to engage students in assessing their own performance and learning. For Stage 3, the technology education teacher or engineering teacher would write a plan similar to the following:

Prerequisite Enabling Instruction

"Utilize a computer as an information management tool" (North Carolina Department of Public Instruction, 2002, p. 166).

Motivating the Student to Learn:

1. *Tell students that they will ultimately end up designing a product as an engineer. However, to do the best design job possible, they will have to use mathematics and make group decisions.*
2. *Lead students in a discussion about ways in which they can use the computer to manage processes like mathematical calculations and decision making processes.*

Direct Instruction:

3. *Introduce students to the various parts of the spreadsheet.*
4. *Demonstrate how to use a spreadsheet by organizing date in columns.*
5. *Explain what functions are.*
6. *Demonstrate how to insert functions and check for correct answers*
7. *Review the demonstration.*
8. *Provide a simple project for spreadsheet use as a guided practice. Help students develop a sample spreadsheet based on a handout as a guide while the teacher circulates to insure that students practice correctly.*
9. *Review what was learned.*

Main Lesson

"Explain how design is related to technology, such as safety, functionality, and economy" (North Carolina Department of Public Instruction, 2000, p. 213).

Review:

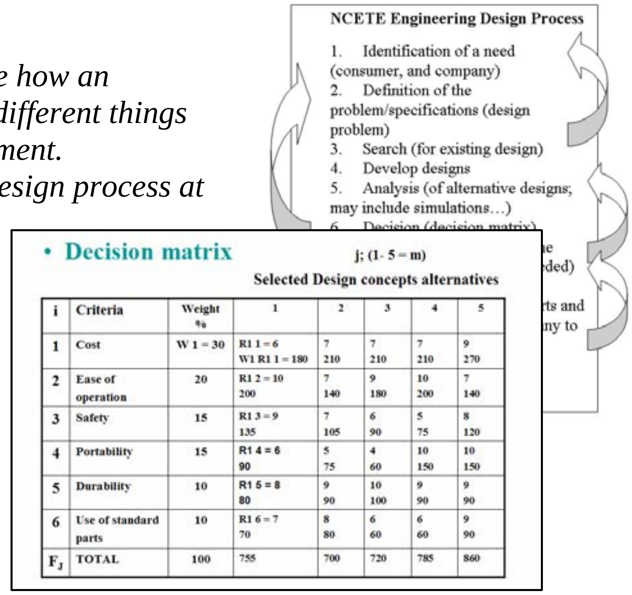
10. *Review what was learned previously about engineering design.*
    - *Students will be able to explain that engineering design is complex.*
    - *Engineering design proceeds in a cycle.*
    - *Designed solutions must use mathematics to optimize designs.*
    - *Designed solutions must applications of science in order to inform designs.*

Motivating the Student to Learn:

11. *Explain to students that they will now have to apply what they learned previously about engineering design and about spreadsheets.*
12. *Show students a video similar to the Tacoma Narrows bridge failure. The failure of the bridge resulted from a lack of wind-tunnel testing and analysis. Mathematics and science are used in several of the steps in the engineering design process.*

Direct Instruction:

13. *Use an engineering case study to illustrate how an engineer's design must take into account different things like cost, safety, and affect on the environment.*
14. *Emphasize the points in the engineering design process at which mathematics and science are applied: Definition of the Problem/Specification, Analysis, Decision, Test Prototype.*
15. *Show students how to construct and use a decision matrix, but later allow them to apply the decision matrix's components to what they previously learned about spreadsheets.*


NCETE Engineering Design Process

1. Identification of a need (consumer, and company)
2. Definition of the problem/specifications (design problem)
3. Search (for existing design)
4. Develop designs
5. Analysis (of alternative designs; may include simulations…)

• Decision matrix

j; (1- 5 = m)

Selected Design concepts alternatives

i	Criteria	Weight %	1	2	3	4	5
1	Cost	W 1 = 30	R1 1 = 6 W1 R1 1 = 180	7 210	7 210	7 210	9 270
2	Ease of operation	20	R1 2 = 10 200	7 140	9 180	10 200	7 140
3	Safety	15	R1 3 = 9 135	7 105	6 90	5 75	8 120
4	Portability	15	R1 4 = 6 90	5 75	4 60	10 150	10 150
5	Durability	10	R1 5 = 8 80	9 90	10 100	9 90	9 90
6	Use of standard parts	10	R1 6 = 7 70	8 80	6 60	6 60	9 90
F_J	TOTAL	100	755	700	720	785	860

Indirect Instruction:

16. *Teach students how to work in groups. Assign groups and assign roles.*
17. *Introduce students to the engineering design challenge. Walk them through the challenge handout.*
18. *Make sure that students understand what is expected of them. Review the rubric with students so they know how they will be graded*
19. *Without giving answers, model how students can proceed with each step as student groups arrive at each step.*
20. *Model how to document the process in a teacher's version of the engineering design notebook. Have a sample engineering notebook on hand for students to look at throughout the challenge.*


Engineering Design Challenge: Food for the World

Scenario
We take a lot of things in our technological world for granted. A reliable supply of clean water for growing crops is one of the technological marvels that we do not think about unless we have to go without food.

Irrigation systems provide water to crops so they will grow. Some systems are modern and require a lot of energy. Other systems are more simple and well suited for cultures with less technological sophistication than that found in the United States.

Water systems need several characteristics in order to operate efficiently. They need to have a

- water source,
- energy to move the water,
- way to distribute water to the location it is needed, and
- way to control the flow of water.

Your engineering design team needs to design, develop, and implement an inexpensive, working, scale model of a water flow system that will irrigate an olive grove to grow a vitally needed supply of olives in a region in the Middle East where food supplies have been disrupted for a variety of reasons. You should use an engineering design approach to solve the challenge.

Goals, Outcomes, and Expectations
Engineering teams who undertake this challenge should be able to:
1. Explain the aspects of the problem and design solution that are uniquely engineering.

21. *Monitor students to make sure that the groups are following the engineering design process.*
22. *Collect engineering notebooks for each student and provide formative assessment of the process for the current challenge.*
23. *Whenever it is time to use mathematics and science, place special emphasis on their application. Emphasize what has been happening in the mathematics and science classes for the teachers who have been doing curriculum integration with you for this unit.*
24. *End the unit by having students assess their solutions/engineering designs using the same rubric the teacher uses.*
25. *Lead a discussion about what was learned by students using the engineering notebook and the challenge rubric as guides for the discussion.*

The mathematics and science teachers should do the same form of documentation as it relates to what needs to be taught in their respective curricula.

Coordinating Curriculum Integration

As one teacher without a team, you could deliver the curriculum integration (TSM) content by yourself; teachers do this all the time, but a more powerful approach (if you have enough students in common with the other team members) is to coordinate the content deliver among your team members. In order to plan the sequence of instruction, a timeline needs to be developed that shows when each topic is to be taught in each of the three subjects; the mathematics, science, and technology/engineering classes. LaPorte and Sanders (1996) suggest a simple but illustrative format for such a timeline. The chart below is similar to charts that they recommend using.

In the example, timeline of instruction below, the group of teachers decided to teach needed mathematics and science near the beginning of the challenge so that students could you use that knowledge in the front end of the engineering design process. Notice also that some days the science and mathematics teachers are not necessarily teaching concepts related to the engineering design challenge. In this case, the teachers decided that the technology teacher would *primarily* drive the engineering design challenge. However, it is interesting to note that all three teachers appear to want their students present when prototypes are being tested near the end of the unit. This is done so that all three teachers can emphasize the relevancy of technology, mathematics, and science.

Instructional Timeline for Integrated Unit: Bungee Cord

	Technology/Engineering	**Physical Science**	**9th Grade Mathematics**
Day 1	Computer Spreadsheets	-	-
Day 2	Review of Engineering Design Process	Potential Energy	-
Day 3	Conduct Challenge	Kinetic Energy	Review of Real Numbers
Day 4	Emphasis on Math and Science in Certain Step	Types of Energy Lab	Calculating Real Numbers for Engineering Design Unit
Day 5	Emphasis on Math and Science in Certain Step	-	-
Day 6	Emphasis on Math and Science in Certain Step	-	-
Day 7	Engineering Design Challenge Testing of Prototypes	Engineering Design Challenge Testing of Prototypes	Engineering Design Challenge Testing of Prototypes
Day 8	Review and Discussion	Review and Discussion	Review and Discussion

Outcomes:

Teacher proposals that meet the criteria for acceptable challenges, lesson plan and challenge handout (design brief), and student assessment rubric.

Success Indicators:
The teacher's proposal meets the criteria for acceptable challenges. Participant self-reporting on satisfaction.

Intersession Assignment (Homework)

By this time, make sure that teachers are thinking of a number of different places in their curricula in which they can infuse engineering design.

Near the end of spring professional development, they were assigned the task of identifying within their own programs where engineering design can be taught. Then they have to conduct research and development on the efficacy of infusing engineering design into that identified area of the curriculum. During the time between the spring professional development and the summer professional development, teachers will have had a chance to think through the technical nature of the infused concepts and determine whether or not the idea is doable. Teachers must work through the engineering design process in order to more fully investigate the efficacy of their activity ideas and come up with even the prototype solution.

Continue this document with Summer PD and Fall Implementation.