THE ABC'S OF CREATING INFORMED DESIGN ACTIVITIES

Informed design is a pedagogical approach to design that was developed and validated through the NSF-funded NYSCATE Project (New York State Curriculum for Advanced Technological Education) [Burghardt and Hacker, 2003]. Informed design enables students to enhance their own related knowledge and skill base before attempting to suggest design solutions. In this way, students reach design solutions informed by prior knowledge and research, as opposed to trial-and-error problem solving where conceptual closure is often not attained. Informed design emphasizes design challenges that rely on knowledge of math, science and technology to improve design performance. The approach prompts research, inquiry, and analysis; fosters student and teacher discourse; and cultivates language proficiency.

Knowledge and Skill Builders (KSBs)

A key factor that differentiates informed design from other design processes is how the Research and Investigation phase is approached. To provide the foundation for informed design, activity learners are engaged in a progression of ***knowledge and skill builders*** **(KSBs)**. KSBs prepare students to approach a design challenge from a more knowledgeable base. The KSBs are short, focused activities designed to help students identify the variables that affect the performance of the design. They provide structured research in key technology, science, mathematics processes, skills, and concepts that underpin the design solution. They also provide evidence upon which teachers can assess student understanding of important ideas and skills. The final design is "informed" by the knowledge and skills that students acquired enroute to designing and constructing their solutions.

Many design processes, including the informed design process, may be characterized by the following:

1. *Clarify design specifications and constraints.* Describe the problem clearly and fully, noting constraints and specifications.
2. *Research and investigate the problem*. Search for and discuss solutions to solve this or similar problems. Complete a series of guided **knowledge and skill builder activities** that will help students identify the variables that affect the performance of the design, and inform students' knowledge and skill base.
3. *Generate alternative designs*. Don't stop when you have one solution. Approach the challenge in new ways and describe alternatives.
4. *Choose and justify optimal design.* Rate and rank the alternatives against the design specifications and constraints. Justify your choice. Your chosen alternative will guide your preliminary design.
5. *Develop a prototype.* Make a model of the solution. Identify and explain modifications to refine the design.
6. *Test and evaluate the design solution*. Develop and carry out a test to assess the performance of the design solution. Complete or review **KSBs** focused on developing a fair test.
7. *Redesign the solution with modifications*. Examine your design and look at others' designs to see where improvements can be made. Identify the variables that affect performance and determine the concepts which underlie these variables. Explain how to enhance performance of

the design using these concepts and variables.
8. Communicate your achievements. Complete a design portfolio or design report that documents the previously mentioned steps. Make a group presentation to the class justifying your design solution.

GETTING STARTED

We will use the developed of *Drying by Design* (2005) as a sample to reference in the following discussion.

The informed design process is very congruent with Wiggin and McTigue's *Understanding by Design* (2005); in fact that's where we recommend starting. What is it you wish the students to learn? What key ideas, big ideas, are you seeking they understand? Use national and state standards to help you define these.

How did this occur in Drying by Design? We were looking for a middle school, high end, technology education activity that would have significant math, science and technology knowledge requirements. We wanted the activity to illuminate several key ideas; one, the design process including trade-offs, the design elements, testing and evaluation; two, mathematics concepts of area, perimeter, linear and non-linear algebraic equations; three, science concepts of humidity and evaporation. **There are learning outcomes in all three areas to be responsible for.** The Drying by Design activity will be referenced in steps below.

As we conceptualized the project, we thought about how we might assess student understanding and how we might scaffold their knowledge in the MST content areas. We had already selected dehydration as technological area because it appealed to many teachers.

***Note**: It is very important to perform the activity before teaching it, there can be erroneous assumptions made in conceptualizing the activity that come to light when undertaking it.*

Step 1: Create a context for the activity. This does not have to expansive, but should have some credibility with students. *The DbD problem was constructed with the aid of middle school teachers. It is not very long, but sufficient for students to appreciate why they could be completing the design challenge. Once students become invested in the challenge, the context becomes much less important. They focus on the design challenge*.

Step 2: Create the design challenge, specifications and constraints. You will want to control the materials, time and techniques employed. The specifications should relate to the challenge and require that students not be able to employ trial and error, "gadgeteering", methodologies for the solution. *In the Drying by Design example, the dehydrator with the maximum efficiency is the optimum design. Embedded in the efficiency will be factors which are inverse, a shorter time is better, but a longer time will yield more weight loss. Hence, trade-offs (a major conceptual factor in design) are an important factor in student thinking*.

Step 3: Introduce the technology. In this activity these are embodied in KSBs T1 and T2. The first KSB introduces students to the informed design cycle. In subsequent activities, once students understood the design cycle, this is not necessary. *The second KSB, T2, relates to the technology of the design challenge. All engineers and designers rely on prior knowledge of existing designs. Students should research and understand what exists before creating new technological solutions. Sometimes these link very closely with the science KSBs. The end of the KSB should cause students to make a connection to the design challenge, so they can relate the material to solutions they might create.*

Step 4: Introduce the science (or math). In this activity these are embodied in KSB S1. This KSB introduces students to concepts of evaporation and humidity. These concepts are important in science. *It is important that you have resources (or create resources) for students to use. Oftentimes this might involve some experimentation, such as leaving a dish of water out overnight and observing what happens to the water. The end of the KSB should cause students to make a connection to the design challenge, so they can relate the material to solutions they might create.*

Step 5: Introduce the mathematics. In this activity we had a desire to reinforce, and perhaps develop, student understanding of mathematical concepts. These are illustrated by KSBs M1 and M2. In M1 KSB the activity requires students apply math. *The drying of fruit is a non-linear process. The fruit slices will dry quickly at first as the surface water evaporates, and then more slowly as the water must get from inside the apple slice to the surface. In this activity students have to plot and graph data and extrapolate to new conditions. It also introduces the concept of normalized or dimensionless weight which will allow comparison of different initial weights on different designs. The M2 KSB has students think about area, how to calculate it (they need to know area because it is a constraint) for different shapes. Notice that the KSB is very hands-on, it is not procedural. Research has indicated that procedural practice does not lead to transfer of knowledge to new situation (a higher order thinking skill). M2 also asks students to think about slicing an apple and what total area the slices will occupy. In technological design it is often easier to make connections to grade level mathematics than it is to grade level science in middle school. Middle school science is often quite qualitative and deals with living systems, while technology most often relates to physical systems.*

Step 6: Introduce any skill activities needed for the design activity. In the Drying by Design example, none are needed, but you may need students to be able to solder electric circuits, use certain tools. The skill activities should be contextualized to the design challenge.

AT THIS POINT STUDENTS HAVE THE PRIOR KNOWLEDGE AND SKILLS TO ATTEMPT THEIR DESIGNS INFORMED BY KNOWLEDGE AND SKILLS (KSBS).

Step 7: Students will conceive of alternative designs. *Ask for at least two and the sketches should have sufficient detail to indicate important features. Students should label sketches to indicate these features. The focus is not on detailed drawings.*

Step 8: Students justify optimal design. *They argue the case for their design in terms of the KSB knowledge they have just learned. This is an important pedagogical step. If possible, have students present their conceptual designs and why they think it will work to each other.*

Students will learn from one another, it is fine to revise designs based on learning from other teams.

Step 9: Students construct the prototype. *There will be changes in the design as they proceed, they will discover factors they had not considered. This is exactly what happens in industry. However, they should explain why they made the changes*.

Step 10: Test and evaluate the prototype. *Students may require a KSB as to what is a fair test, or how the design might be tested. It is recommended that the testing KSB be done at this point, as it now assumes importance, rather than in the beginning with the other KSBs. Students will learn that the design in all likelihood does not work as well as they planned. They should consider how to make modifications to improve performance or functionality. The students should present the data in charts or graphs that explain their design's functioning. In the case of Drying by Design, they also need to calculate the efficiency*.

Step 11: Sketch or photo of final design prototype. *If it is a photo, it should be labeled and perhaps dimensions indicated. The sketch can meet course standards. However, the sketch is not the most important feature of the Drying by Design activity. This project's learning outcomes relate to math, science and design.*

Step 12: Recommendations for redesign and communication to the class. This is another important pedagogical feature. *The recommendations should be required to connect to math, science and technology understanding. If the students know that they are presenting to their peers (and perhaps an external constituency) they will most often have focus*.

ASSESSING STUDENT LEARNING. There are a variety of ways to assess student learning, examining the KSBs they complete (you cannot assume team completion reflects all members knowledge), completion of an individual design portfolio, questioning during class, pre/post assessment. Regarding the pre/post assessment, you will often (hopefully) include information/knowledge the students do not know. The assessment will probably be short answer and/or multiple choice. It should require a knowledge level consistent with the goals of the unit. The Drying by Design pre/post assessment is challenging. An important strategy is to give students credit for honestly answering, or attempting, the questions. They will get an A, it will count for x% of their grade if the assessment is truly attempted. Students will often have anxiety about taking a "test" and not doing well. The aforementioned strategy often minimizes this anxiety. The same assessment is given at the end of the unit so you can gauge improvement on this assessment instrument. Often teachers will want to give an end-of-the-unit exam; it is possible to expand the pre assessment with additional questions. However, when doing the pre/post assessment, just analyze the responses to "pre" questions.

Reference:

Burghardt, M.D. & Hacker, M. (2003). The New York State Curriculum for Advanced Technological Education. Retrieved from www.hofstra.edu/nyscate 25 October 2005.

Wiggins, G. & McTigue, J. (2005). *Understanding by Design*. Association for Supervision and Curriculum Development. Alexandria, VA.