Informed Design: A Contemporary Approach to Design Pedagogy

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Design as The Core Process in Technology

The Standards for Technological Literacy [ITEA, 2000] indicate the centrality of design to the study of technology, "Design is regarded by many as the core problem-solving process of technological development. It is as fundamental to technology as inquiry is to science and reading is to language arts" [p. 90]. Design in technology education most closely allied with engineering design. For instance, The Accreditation Board for Engineering and Technology (ABET) defines design in the *Criteria for Accrediting Engineering Programs* as "the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences and mathematics and engineering sciences are applied to convert resources optimally to meet a stated objective" [ABET, 2000]. This is consistent with work of Erich Bloch [1986] who defined engineering design as design under constraint in that the design solution must satisfy such constraints as size, weight, manufacturability, reparability, safety, environmental impact, and ergonomics.

Design as an Instructional Strategy

In recent years, there has been a growing recognition of the educational value of design activities in which students create external artifacts that they share and discuss with others [Soloway, 1994; Papert, 1993; Resnick, 1998]. A synthesis of the literature reveals that pedagogically solid design projects involve authentic, hands-on tasks; use familiar and easy-to-work materials; possess clearly defined outcomes that allow for multiple solutions; promote student-centered, collaborative work and higher order thinking; allow for multiple design iterations to improve the product; and have clear links to a limited number of science and engineering concepts [Crismond, 1997].

The National Research Council's *How People Learn* hails instruction where students monitor their understanding and progress in problem solving. Research reveals that experts consider alternatives, note when additional information is required, and are mindful if the chosen alternative leads toward the desired end [Bransford, 1999]. These strategies are central to the culture of design.

However, in classroom settings most problems are usually well defined in school (given this, find that), so students have little experience with open-ended problems. Technological design problems, however, are seldom well defined. The design process begins with broad ideas and concepts and continues in the direction of ever-increasing detail, resulting in an acceptable solution [Thacher, 1989]. So using design in the classroom can be challenging as students are not familiar, or initially not comfortable, with the open-ended nature of design. This can also pose problems for teachers who must relinquish directive control, however, it also provides opportunity to use constructivist pedagogical practice to engage students in their own learning. The informed design process discussed in this article, and the underlying pedagogical support methodology provide a way to optimize the use of design as a pedagogical strategy.

Pedagogical Rationale for Design

As a pedagogical strategy, design activities have great potential to:

- Engage children as active participants, giving them greater control over the learning

process;
- Assist students to integrate learning from language, the arts, mathematics, and science;
- Encourage pluralistic thinking, avoiding a right/wrong dichotomy and suggesting instead that multiple solutions are possible;
- Provide children an opportunity to reflect upon, revise, and extend their internal models of the world;
- Encourage children to put themselves in the minds of others as they think about how their designs will be understood and used [Resnick, 1998].

All too often however, design is not used to maximum pedagogical advantage in the classroom. As an instructional strategy, design has all too often focused on the product rather than on the learner. Design is often characterized by 'gadgetering' and trial-and-error problem solving where students do not always gain important (i.e., standards-based) conceptual understandings.

Informed Design

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 math and science knowledge to improve design performance. The approach prompts research, inquiry, and analysis; fosters student and teacher discourse; and cultivates language proficiency.

Each phase involves monitoring performance against desired results and making appropriate modifications at various points. Typically, trade-offs are required to address design criteria optimally. Characteristically, some design decisions are made without complete knowledge and must be revisited.

Engineers and other designers do not always follow these steps in a sequence. Often, they move back and forth from one phase to another as needed. However, it is useful to point out that the phases are important components of any engineering design process. As with most design cycles, the informed design cycle is iterative and allows, even encourages, users to revisit earlier assumptions and findings as they proceed. It was created with knowledge gained from works in cognitive science and learning.

Knowledge and Skill Builders

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.

Figure 1 depicts the overall informed design cycle. The cycle uses familiar design cycle terminology, however underlying the phases are important enhancements. The phases are described as follows:

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. Identify related problems, issues, and questions. 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. Reflect on what is the best design; justify your choice based upon ratings, and new learning acquired from knowledge and skill builders. Your chosen alternative will guide your preliminary design.
5. *Develop a prototype.* Make a model of the solution. Identify modifications to refine the design, and make these modifications.
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. Collect and analyze performance data to show how well the design satisfies the problem specifications and constraints.
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 which science concepts underlie these variables. Indicate how to use science concepts and mathematical modeling to enhance performance.
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.

An Example in a Familiar Context

Bridge building design projects have been used for many years, however they often are not informed by mathematics, scientific, and technological knowledge of the construction of various types of bridges. All too often, bridges are loaded to the point of failure, strengthened at the failure point, and rebuilt without delving into the cause and reasons for failure. KSBs for a bridge building project might include:

- Investigation and construction of simple beam bridges, suspension bridges, arches, and truss bridges.
- Investigation of tension and compression in bridge members.
- Gathering and plotting data to reinforce important mathematics and science inquiry skills.
- Determining and developing a fair test to focus on the design specifications and how to test for them.

To encourage the use of thoughtful alternative solutions, the problem statement is more open-ended than the traditional one of building a bridge to hold the most weight, a single criterion. In the new situation, the goal is to design and construct a cost-effective bridge that will hold the most weight for the least cost, while meeting a minimum load specification, two criteria that may be inversely related. This more accurately models engineering practice. Materials have different costs associated with them, which can encourage a variety of designs approaches and foster critical thinking about why they will be the best. [Hacker and Burghardt, 2004]

Another important feature of the informed design process is having students justify their solutions at several points along the way. Ideally, students would present their findings to the class at these points and engage in discourse with other students and the instructor. In selecting an optimum solution, the goal is to have students indicate why one particular solution is the best based on the knowledge they gained. As they construct the prototype, they will make modifications. Again it is important that this be documented before proceeding to the testing and evaluation phase. There may be iteration between the testing and prototype phases as well. Interrogating students for their critical thinking at these points has them reflect on what they are learning, embedding knowledge and skills more deeply. The redesign step seeks students to reflect on new design if time allows. Reflecting on what they have learned is an important part of the informed design process. Reflection comes at multiple times in the process, so students become accustomed to thinking this way. Communicating your final design to others is documents the reflection and thought processes used in creating the design.

Research Base

The informed design process was created as part of the NYSCATE NSF curriculum materials development project. Of the thirteen modules developed, eight are intended for use on the high school level and can be modified for use in middle school; the remaining modules are for use in community college technology courses. The modules were developed using strategies of backwards design [Wiggins and McTigue, 1998] as replacement curriculum for existing technology and science courses. As part of this National Science Foundation project, student learning was evaluated by the Center for Advanced Study in Education (CASE) at the Graduate Center at the City University of New York.

There was a great deal of enthusiasm expressed by teachers and students for all the modules. The Project evaluators indicated that the technology and design components were consistently understood by students and teachers, and that the understanding of science and mathematics concepts varied depending on how explicitly they were addressed by the KSBs. For instance, in one module where students designed a food dehydrator (Drying by Design), the three field test teachers agreed that students learned important technology concepts and important design processes and two teachers reported that their students learned important math concepts and science concepts.

Students were questioned about what they perceived they learned. The following summarizes their responses:

- Students **strongly agreed** that they learned important science, technology and design concepts
- Students **strongly agreed** that they learned from the design task so that they could do it better id they did it again
- Students **moderately agreed** they learned important math concepts.

The modules developed through the NYSCATE Project use informed design as the core instructional strategy. The modules are shown in Figure 2, below.

AREA / GRADE	MATERIALS AND MANUFACTURING	INFORMATION TECHNOLOGY	BIO/CHEMICAL TECHNOLOGY
Gr. 9-10, HS	Drying By Design Mapping Through Remote Sensing	The Help Desk	Genetic Testing
Gr. 11-12, HS	Liquid Crystals	Introduction To Networks	Polymers
Gr. 13, CC	Control Systems	Paving The Way To The Internet	Solutions And Dilutions
Gr. 14, CC	Design For Manufacture	Gatekeeper To The Internet	Purifying Proteins By Design

Figure 2. NYSCATE Modules

Conclusion

The results from reviews by experts, pilot testing and field-testing of the modules has shown that informed design and the pedagogical strategies that support it are effective. The informed design process contextualizes learning and applies the latest constructivist pedagogical practices to enhance student learning. This process complies with current understandings of how students learn and how to create effective learning environments for them.

Note: For related information on the effectiveness of using design technology in the elementary school, Koch and Burghardt [2002] provide an analysis of over 40 action-research masters' theses with this as their research topic. Again design technology is shown to enhance learning for all students.

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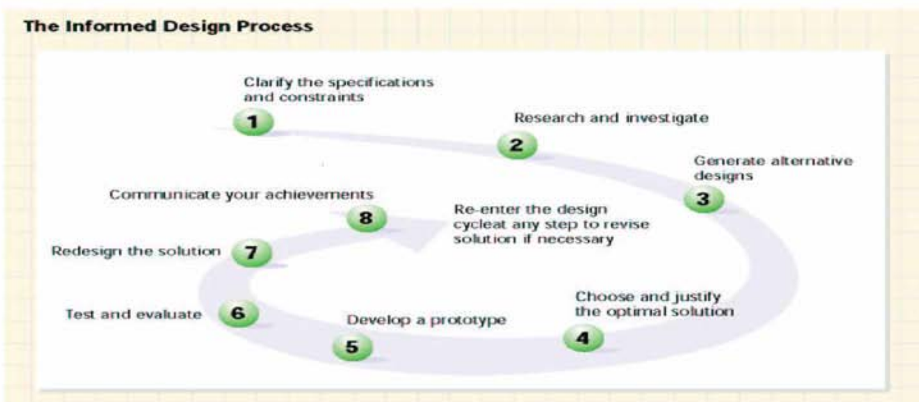

Hacker and Burghardt, 2002

Figure 1. Informed Design Cycle