Teaching Technology and Engineering

By Marc J. de Vries, Michael Hacker, and David Burghardt

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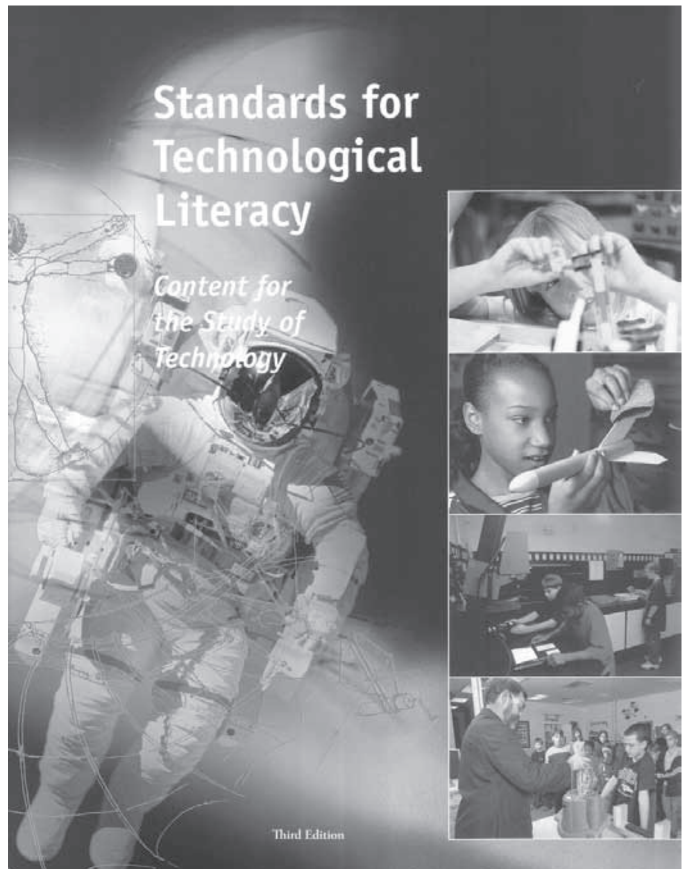

Standards for Technological Literacy.

A Research Study to Identify Overarching Themes and Instructional Contexts in Technology and Engineering Education

Introduction

The publication of *Standards for Technological Literacy: Content for the Study of Technology* (ITEA/ITEEA, 2000/2002/2007) represented a major step forward in identifying the educational components necessary for life in a technological world. But this list of standards, though substantial, does not clearly identify the components that are most fundamental. In this article we describe an international effort to define the overarching, unifying themes, or *big ideas,* that cut across domains and thus give insight into the holistic nature of technology and engineering. Together with their main contexts, these overarching themes form a framework for developing curricula and classroom materials for technology and engineering education.

Teaching about technology and engineering is a challenge, given the impressive speed of technological development. If the goal is to educate for the future instead of the present or past, rapid changes in the technological domain make this work challenging. But there is an approach that is well suited to the kinds of changes that technology undergoes; it involves using those themes that have remained constant throughout history. A large number of concepts have been identified in the *Standards for Technological Literacy* document. Not all of them, however, are overarching ideas that are fundamental to the entire domain of technology and engineering; some are more specific, applying only to certain subdomains.

Which ones are more generic? Which are less fundamental? To answer these questions, we consulted a group of experts in several technology and engineering-related disciplines.

The Research Study

The approach we used for this research was a modified Delphi study that was conducted during the summer of 2009. For our study, we consulted 32 experts from nine countries and from a variety of ETE-related disciplines including philosophy and history of technology, science and technology communication, engineering education, and technology (teacher) education. The researchers (de Vries, Hacker, Rossouw) suggested these experts because they had published works related to the nature of technology and engineering, and therefore could reasonably have been expected to have sophisticated opinions regarding major themes and contexts of technology and engineering.

In a traditional Delphi study, experts are asked for their opinion on certain issues and then in following rounds are confronted with each other's opinions so that they can adapt their own opinion in that light. This process tends to lead to consensus after several rounds of confrontation. The modified Delphi used in this study provided a set of research-based ideas about themes and contexts as a beginning and invited the expert panelists to add or reject these ideas. This modified Delphi also included a face-to-face follow-up reconciliation meeting that involved a subset (n=9) of the expert panel. Members of the subset group were able to clarify and add additional structure to the Delphi panel results. After three Delphi rounds and the reconciliation meeting, we were able to establish a consensus.

In our study, we asked not only for important, transferable ideas (major themes/overarching concepts) in technology and engineering, but also for suitable contexts that could be used to teach these ideas, as research indicates that context is crucial to understanding. In the past, educators believed that if ideas were taught generically (or taught in a single context) learners would be able to apply these ideas in different contexts. This thinking has fallen into disfavour, and current educational thought maintains that to develop a deeper and more holistic understanding, learners should become acquainted with an important idea and revisit that idea in a variety of contexts. Then they will be better able to understand the idea in its fullest sense and apply the idea within hitherto unfamiliar contexts (Bulte, et al).

On the basis of the outcomes of our Delphi study, we propose a set of unifying themes and a set of contexts that can be used as the framework for curriculum development in ETE. In Table 1 we present the themes and subconcepts, and in Table 2 we present the contexts.

Themes

The themes in Table 1 deserve explanation. The Delphi experts produced a list of ideas, some of which were more fundamental and generic than others. The research team analyzed this list and ranked some of the ideas as primary (unifying themes) and some as second-level concepts. The second-level concepts are subconcepts of the unifying themes. For instance, design (as a verb) is an overarching theme under which we find more specific subconcepts such as making trade-offs, drawing up specifications, assessing solutions, and inventing.

Likewise, when we consider *technological systems* as a unifying concept, subconcepts such as artifacts (as part of a system), function (of a system), and structure (of a system) can be identified. In a similar way, the broader theme *resources* can be divided into specific resources: materials, energy, and information. *Modeling* may be divided into representational and predictive subconcepts. *Human values* is also regarded as an overarching theme in ETE, and under this thematic heading specific value-related ideas such as sustainability, risk and failure, social interaction, and innovativeness are grouped.

Themes	Subconcepts
Design as a Verb	Optimization Making Trade-offs Specifications Technology Assessment Invention
Modeling	
Systems	Artifact (Design as a Noun) Function Structure
Resources	Materials Energy Information
Human Values	Sustainability Innovation Risk, Failure Social Interaction

Table 1. Themes and Subconcepts

Contexts

The outcome of the Delphi study was that two types of contexts could be recognized. One type consisted of the contexts that by now are considered traditional in ETE curricula and textbooks used in the United States. These contexts—construction, production/manufacturing, transportation, biotechnical, and communication—fall under the umbrella term "technological systems" and are part of the technological literacy standards. But in addition to these classical contexts, the experts in this study generated a list of contexts related to what can be called "personal and global concerns." These are the contextual issues that are at stake when we think of a sustainable future. In this subset we find such contexts as water, energy, food, health, and security.

In the "personal and global concern" approach, our use of the term "context" is used to describe the circumstances in which students can be personally involved in ETE activity. The student is seen as a participant rather than as an observer. Participating in an electronic discussion group can be a context, as can being part of a transportation system by driving or riding in a hybrid vehicle, playing on an amateur sports team, or visiting a medical facility. Students' direct participation sets the stage for meaningful, just-in-time learning.

By looking closely at the more traditional contexts, we realized that, in fact, they too can be related to human and social concerns and needs. Shelter, mobility, and communication, as well as an availability of artifacts for daily use, are among these needs. Thus we developed the list of contexts presented in Table 2.

Contexts	
Contexts Based on Technological Systems	**Contexts Based on Personal and Global Concerns**
Construction	Shelter
Production/Manufacturing	Artifacts for Practical Purposes
Transportation	Mobility
Biomedical Technologies	Health and Safety/Security
Communication	Social Networking
	Food
	Water
	Energy

Table 2. Contexts

Implications for Teachers

What is the next step? Teachers and curriculum developers can use the identified themes and contexts to elaborate a curriculum structure and classroom materials. There are two alternative ways to move forward: one is a thematic approach, and the other a systematic or disciplinary approach. In the thematic approach, one starts with a context, teaches a variety of themes and subconcepts in this context, and then moves to the next context. That context is then used for revisiting some of the themes and subconcepts and for teaching other, new ideas. Thus learners work through the list of contexts one by one and gradually develop an understanding of the various themes and related subconcepts.

In the systematic or disciplinary approach, one starts with a theme, teaches it in a variety of contexts, and again gradually develops an understanding of that theme at a deeper and more holistic level. The context-based approach will result in a curriculum structure with headings such as water, health, and security. The thematic approach will result in a curricular approach with headings such as designing, modeling, systems, resources, and human values.

Prior Approaches

A well-known example of a theme-based curriculum structure is *The Man-Made World*, a textbook published in 1971 that resulted from the Engineering Concepts Curriculum Project course at the Polytechnic Institute of Brooklyn. According to the authors, "through its broad approach, the course aimed to help students develop insights useful in coping with social, economic, political, as well as purely technical problems" (David and Truxal). Another example is the Principles of Engineering Curriculum developed by the New York State Education Department in 1987. This curriculum was adopted by teachers in over 100 schools in New York and schools in twenty other states. The focus was on using case studies in different contexts (e.g., auto safety, automation and control, structural design) that revisited a set of engineering themes.

Next Steps

A logical next step is to develop a curriculum framework that fleshes out the concepts and skills that students at the various grade levels are expected to know and be able to do. Such a framework would embed standards-based knowledge and skill into a themes/context matrix as shown in Figure 1.

The framework would identify the particular concepts and skills to be taught at each grade level that relate to each

	EXAMPLES OF CONTEXTS SUGGESTED BY THE RESEARCH STUDY EXPERTS															
	Energy				Shelter				Water				Food			
	K-2	3-5	6-8	9-12	K-2	3-5	6-8	9-12	K-2	3-5	6-8	9-12	K-2	3-5	6-8	9-12
THEMES																
Design																
Modeling																
Systems																
Resources																
Human Values																
DESIGN ASSESSMENT TASKS TO BE DEVELOPED FOR EACH GRADE LEVEL WITHIN EACH CONTEXT																
DESIGN ASSESSMENT TASKS (DATs)	K-2 DAT	3-5 DAT	6-8 DAT	9-12 DAT	K-2 DAT	3-5 DAT	6-8 DAT	9-12 DAT	K-2 DAT	3-5 DAT	6-8 DAT	9-12 DAT	K-2 DAT	3-5 DAT	6-8 DAT	9-12 DAT

In each cell, standards-based skills and concepts will be identified.

Figure 1. ETE Theme- and Context-based Curriculum Framework

of the themes within the specified context. Instructional activities would be developed that would challenge students to engage in design problems and, through them, demonstrate their ability to recognize and apply the unifying themes within the context. These design assessment tasks (DATs) would be developed at age- and grade-appropriate levels and serve as an opportunity for students to engage in design-driven, criterion-based performance assessments that would focus on the thematic, contextual, and conceptual understandings and skills to be learned. Curriculum would be developed from the framework to fit the preferred delivery systems at elementary, middle, and high school.

In Summary

We believe that these lists of themes and contexts, generated by a select international group of experts in various ETE-related fields, can help us take an important step forward in identifying the disciplinary core of technology and engineering education, and in forming an educational strategy for teaching and learning that core. We invite others to consider developing curricular frameworks and materials in the context-based and thematic modes.

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Those who are interested in reading the original Delphi *CCETE Final Report* can find it at http://hofstra.edu/pdf/Academics/Colleges/SOEAHS/ctl/ctl_finalreport_CCETE_Nov_6.pdf#C

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Ad Index