IDEAS

1. Design Methodology in University ScienceTechnology and Society (STS) Programs

by Marc J. de Vries

WHAT IS DESIGN METHODOLOGY?

Design is a core activity in technology. It is not possible to communicate what technology is without mentioning design. Design integrates phenomena of the natural sciences, technological tools and methods, and social demands and constraints. Analyses in design methodology show how scientific, technological, and social factors interact in the creation of new products and processes. If we accept Bochenski's (1965) view that methodology is the theory of the application of the laws of logic to various fields, then design methodology is the study of how a logical use of different types of knowledge takes place or can take place. Although rather narrow, this definition emphasizes that methodology is not only the study of methods in the sense of prescriptive step models.

Design methodology as an academic discipline is only about 30 years old. At first, design methodology was concerned with producing prescriptive representations of design processes, usually based on the two premises that:

1. the description of the design process is independent of the technology or product type that is involved, and
2. the design process includes (a) analysis of the problem, (b) synthesis of possible solutions, and (c) evaluation of the design proposal.

Both premises were challenged by research which showed that there are significant differences between the design of different types of products and that designers, throughout the design process, engage in analysis and also synthesis and evaluation activities. It also became clear that prescriptive design process models can have a negative influence on the design process. That is to say, they tend to become so autonomous that relationships of changing scientific, technological, and social contexts are forgotten because all effort is put into "blindly" following the steps in the process.

Today two "cultures" of research in design methodology still exist (de Vries, 1993). One culture focuses on the "internal" design process and does not consider social factors. It usually includes four groups:

1. Practitioners, particularly from construction engineering and mechanical engineering, who represent the design process with flow charts and step models;
2. Cognitive psychologists, who study the way designers think;
3. Experts in business management, who develop methods for relating design to elements such as production, logistics, and marketing; and
4. Computer experts, who work on software that supports design activities.

The other culture focuses on the scientific and social context in which design activities take place and, in particular, the various scientific and social factors that influence design. Here we find historians, who study the way designs have evolved during different historical epochs and among different settings; philosophers, who study the nature of the knowledge that is involved in design; natural scientists, who study science-design relationships; and sociologists, who focus on the social factors that influence the design.

It is in the second culture that we find the science-technology and technology-society relationships which are the key issues in STS programs. This culture, which is the focus of this article, is often known by its broader name *technology dynamics*. Vincenti (1990) characterized the types of knowledge that designers use and the way these types of knowledge are developed. This belongs to the field of design methodology (more specifically, design epistemology), but was not qualified as such explicitly. Usually the term *design methodology* is equated with the first culture. However, the meaning of the term *methodology* according to Bochenski (1965) does not support his equation.

TYPES OF STS PROGRAMS

In this article, two types of academic programs in which scientific-technological and social knowledge are brought together are distinguished.

1. Engineering based programs that educate engineers with a thorough basis of engineering know-how and some knowledge of the social circumstances under which technological developments take place. The purpose is to provide knowledge of social needs and constraints as they develop new technologies.
2. Social science based programs that educate social scientists with a special focus on technological developments.

Programs of the first type are usually concerned with the development of new technologies that must consider social factors. Engineers trained in such programs use insights of scientific-technological and social factors to make design decisions. Programs of the second type deal more with the consequences of implementation and diffusion of new technologies in society. Here an understanding of the technology itself is necessary to understand the way it is implemented in certain parts of society. The roles of various actors in this process are also considered.

Some programs have a hybrid character. For example, the Technology and Society program of the Eindhoven University of Technology trains engineers who can contribute to policy making related to technological developments. These engineers do not develop new technologies themselves, but carry out research that supports technology policy making.

The first type, the engineering based STS programs, yield opportunities for integrating design methodological studies into the program. Here design methodology could play the role that technology assessment plays in the second type of STS programs that are social science based. In a way, design methodology and technology assessment are analogous: Both are aimed at integrating scientific-technological and social know-how for decision making about technological developments. The difference is that design methodology supports decision making for development of the technology, and technology assessment supports decision making for the implementation of the technology. The boundary becomes blurred when technology assessment moves into the direction of technology assessment, in which impact analyses are used to influence the way the technology is developed (Smits, Leyten, & Geurts, 1987).

Design methodology can also be regarded as complementary to theories in technology dynamics, such as social constructivism, that focus on social actors while design methodology focuses on factors or phenomena (natural and social).

STATUS OF DESIGN METHODOLOGY IN STS PROGRAMS

Design methodology does not seem to play a vital role in most STS programs. Surprisingly, this holds for both categories of STS programs described above. One would expect that in the engineering based STS programs, design methodology would already be present. The lack of design methodology in STS programs could be the difficulty in making real integration of scientific-technological and social know-how. Since most programs are currently multidisciplinary, having several separate disciplines represented, there are difficulties in achieving integration. Because design methodology is aimed at making this integration, it could make a relevant contribution to STS programs.

These remarks are based on this reporter's review of a number of different STS programs worldwide. This included Mitcham's survey of STS programs in the United States (Fricke, 1992) and information derived from descriptions in promotion brochures.

Generally, it should be kept in mind that when the phrase *design methodology* is not mentioned, that does not mean that the concept is not there. But even if it is represented, the manner by which social factors are integrated in product design in both engineering or social studies based programs is not explicit.

ONE WAY TO DO IT

The Eindhoven University of Technology (EUT) teaches STS programs. Design methodology is taught in a compulsory course, Design Methodology for STS, and two electives, Special Topics in Design Methodology and Environmental Issues in Design Methodology. In the compulsory course:

1. students are acquainted with the basic concepts of experience-based technologies, macrotechnologies and microtechnologies, and the concept of multifactorial design methodological analyses;
2. these concepts are illustrated by case studies: bridge design, the Brabantia corkscrew (de Vries, 1994), the Philips Stirling engine (de Vries, 1993), and the Philips Plubicon (Salemijn & de Vries in Kroes & Bakker, 1992); and
3. a brief survey of other approaches in design methodology is given.

As an extension of the preceding course, special topics in Design Methodology explore the various approaches in design methodology in more detail and additional case studies are discussed to illustrate the idea of multifactorial analyses in design methodology.

The second elective course focuses on design for sustainability and includes case studies of multifactorial analyses to show their relevance for green design (e.g., Stirling refrigerating equipment, the three-way catalyst) and new developments in methods for green design (e.g., life cycle analyses, relationships among the design variables of form, material, and treatment). These methods are illustrated with case studies that have been reported in some Dutch projects.

The content of design methodology education at Eindhoven was selected to fit the general goal of educating engineers who are able to integrate technological and social factors into the decision- and policy-making process for developing and/or implementing technology. Toward the end of their studies at Eindhoven, students engage in case studies in an industrial setting. Much of the success they have achieved in these real situations can be attributed to their design methodology abilities and techniques.

DISCUSSIONS ON THE FUTURE OF THE EUT STS PROGRAM

The success of such studies does not mean there are no problems. In fact, the EUT STS program faces the same problems that Cheek (1993) identified for STS programs for both primary and secondary education:

1. Opposition from the traditional programs (in this case the engineering programs),
2. Staffing (finding faculty members who combine a technological and a social science background), and
3. Multidisciplinarity (making a real integration of technological and social know-how).

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Details on the Eindhoven programs as well as the universities that were surveyed can be obtained by writing or emailing the author.

2. Simulation in Employee Training Achieves Risk Management

by Phillip S. Waldrop

"The importance of overcoming basic ignorance and fear and developing a common understanding of capabilities, limitations, and implications is critical to quelling worker and management fears" (Giffi, Roth, & Sean, 1990, p. 321).

To better establish the context for the simulation and its importance, a brief review of the factors leading to changes in production, some specific changes, and the change effects upon workers are discussed. Presented here is a case study of how the top management of one small company sought to communicate with its employees. The goal was to demonstrate effectively with a hands-on instructional technique the problems and limitations inherent in the traditional approach to manufacturing, in contrast with the merits of other new approaches, which tend to create some turmoil during their adaptation and implementation in the firm. The instructional technique described here is available to other firms and for use in academic programs in which technology and management professionals are prepared. The simulation effectively, clearly, and meaningfully teaches the ideas and benefits underlying the new approaches.

FACTORS LEADING TO CHANGE

In recent years much of the published material has focused on the benefits of methods and techniques that are often lumped under the category of "World Class Manufacturing." These imply that to survive in a very competitive global economy, companies must effect improvements in key areas of cost, quality, and scheduling. Two common approaches that address these key areas are cellular production organization cells with teams and just-in-time (JIT) production operation.

Such approaches are "buzzwords" in today's literature, the meanings of which are fairly well understood by those who have studied them. They are likely to be less understood by many who are impacted by them in their workplace. The changes suggested by the buzzwords involve breaking away from traditional and familiar methods that have provided the fabric of the company's internal "culture." Very large and prominent industries have often led the way in application and implementation of such approaches because they have the depth of resources to plan, invest, and manage such major changes. Yet the vast majority of manufacturers in and beyond the United States are small companies that may face proportionately greater risk if their efforts to effect change do not succeed. A 1994 survey of advanced manufacturing efforts, conducted by the Computer and Automated Systems Association of SME, found that 75% had failed, and that efforts to re-engineer business processes failed 80% of the time (Owen, 1996). A critical element of risk is "user acceptance" of new methods and tools: members of the workforce must understand and accept the goals, objectives, and potential benefits of what is likely to be a major change in their working environment and jobs. Acceptance of change may be particularly important as team concepts such as empowerment in decision making are introduced.

COMPETITIVE DEMANDS, CELLS, AND JIT

Cells and JIT are related to what may be called time-based competition. In the past, competitive emphasis was on low price; after World War II, the Japanese, seeking economic recovery, first entered the U.S. market with low-priced goods. Under the influence of such persons as J. Edwards Deming, there were shifts toward higher quality, a competitive thrust which is still a significant area of study and influence on change for competitive survival (Deming, 1986; Hayes, Wheelwright, & Clark, 1988). Industry constantly strives for lower internal costs in order to meet market price demands, and product quality has generally improved and continues to be refined in all types of products.

Today, far more sophisticated consumers expect both good price and quality. While still striving for continuous improvement of cost and quality, industry now faces major competitive pressure in regard to time-to-market. From product concept to presence on the store shelf or showroom floor, product development and production timelines are shrinking (Wantuck, 1989). Firms that fail to get new products into the consumers' view quickly will typically lose significant market share to their competitors (Steudel & Desruelle, 1992). Product competition today also involves pursuit of consumers through introduction of new products and offerings of many variations to match the varied preferences of a diverse consumer base.

Such dynamics have negated much of the old economy-of-scale basis for production operations, and flexibility is now a key driver. Methods such as concurrent engineering help to reduce the design timespan, while in the production area cellular organization of the factory and JIT processing seek to get the product built and out the door (Giffi et al., 1990).

Historically, production operations and facilities were organized by process type (e.g., machine shop, pressworking, assembly, and finishing). However, the cellular approach involves organizing the plant into smaller process areas, typically based on a so-called group technology arrangement. Parts and/or assemblies are processed in dedicated work cells designed for efficiency by having their resources focused on a narrowed range of similar product/process combination (Nolan, 1993).

JIT operations are primarily focused on reduction of inventory, with major benefits including reduction of investment in raw materials, work in process, and finished goods; reduced potential for goods spoilage or obsolecence; and smaller batches of work-in-process in which quality problems may hide (Kobayashi, 1990).

CHANGE CHALLENGES THE WORKFORCE

The major changes involved in converting from a traditional factory layout to cells, and from narrow-scope traditional job descriptions to the multiple responsibilities and team decision making typical of cells and JIT, can affect the attitudes, morale, and performance of employees, supervisors, and managers. For example, to more uniformly balance workloads among team members within a cell, instead of simply being a lathe operator, a person may be trained on several or all of the process skills needed in the cell. Individuals may be trained to inspect their own work and their cell co-workers' work, and also to manage their own processes. This represents a major shift in the scope and nature of responsibility. Years ago, employees tended to complain of boredom from repetitive operations, while more recently "studies indicate that workers tend to feel threatened if they have to make decisions on the job"(Amrine, Ritchie, & Moodie, 1987, p. 366).

Management must consider and balance human factors along with technology, preparing workers for impending changes. Nyman (1992), in discussing flexible manufacturing cell (FMC) implementation success, stated that "it's been proven that ignoring people does not produce good results. Some technically sound FMCs have been outright failures because the needs of people were overlooked. As a consequence, time and money in quantity should be reserved for communicating plans, soliciting input, training, retraining, team building, managing change, and problem solving" (p. 39). It is human nature to enjoy stability; the process of change and the unknowns of the future tend to be a barrier to acceptance and morale. What must be expressed by management and understood by the workers "is the vision of what the organization is about and what its goals are" (Hayden & Johnson, 1996). Given the major effort and investment involved in planning and implementing factory conversions, it is essential that all employees be provided proper information and insight into the goals, objectives, and subsequent benefits of the future situation. But to simply throw out buzzwords such as *cells* and *JIT* is not sufficient. Management needs to communicate the benefits to be derived from the dramatic change so that people can recognize it at a cognitive level that will allow acceptance and, thereby, reduced risk.

THE SIMULATION

This was the challenge that faced Santech, a small firm in Fort Worth, Texas. Its president, Michael Deese, has been very successful in refocusing his firm's product line to what it does best in a "niche," and then recreating the facility and operating structure to maximize the improvements in cost, quality, and scheduling. He decided that to get his employees to understand and accept (as opposed to simply being told about) the forthcoming changes, a simple simulation exercise would be appropriate and effective; he developed a simple tabletop simulation package that has proven highly successful with Santech employees. This reporter observed the exercise on-site at Santech and subsequently procured a simulation kit for use in the industrial management/manufacturing program at Georgia Southern University.

The simulation exercise involves six participants and a facilitator. Additional audiences or trainees may effectively learn through observation of the activities. A kitted set of materials contains all items required, including instruction sheets for the facilitator and participants. Facilitator instructions include, for each simulation phase, statements of quality objective, logistics arrangements, guidelines for the exercise, description of expected changes from the prior phase, and lessons to be learned.

A key component is a chart (Figure 1) used to record the observed productivity indicators from each completed phase of the simulation, including:

- Time to assemble the first plane off the line (cycle time),
- Total good planes produced,
- Total planes for rework,
- Total planes in WIP, and
- Total planes scrapped due to defects.

Six Minute Run	Total Good Planes	Total Planes For Rework	Total Subassy For Rework	Time For 1st Plane Done	Reasons for Difference
#1					
#2					
#3					
#4					
% Change 1-4					

Figure 1. **Observed productivity indicators.**

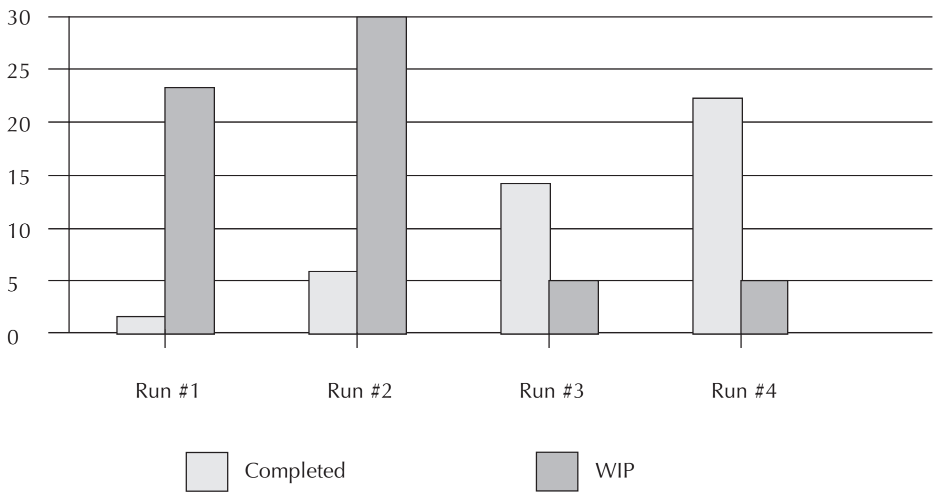

Figure 2. **Throughput.**

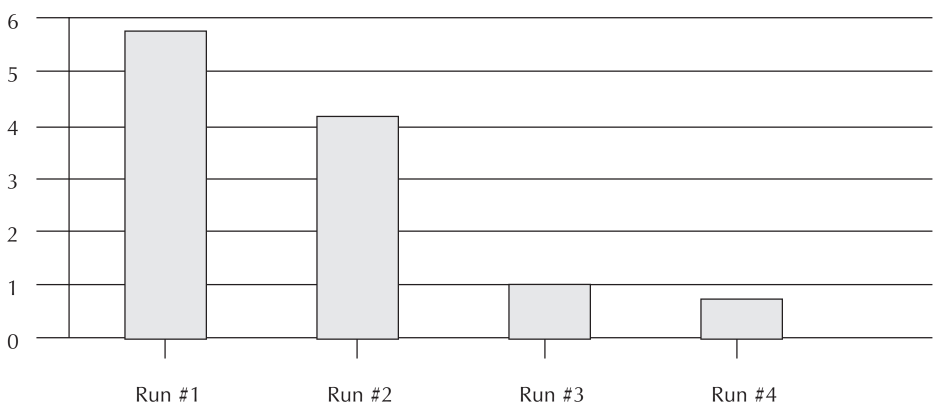

Figure 3. **Cycle time (first completion).**

The simulation activity begins by providing an oral introduction to the activity and its purpose. Then, participants are arranged around a large table in an indirect order of tasks—comparable to the often illogical factory floor pattern of traditional process-oriented production—with product materials stored in a "warehouse" so that workers must make periodic trips away from their work stations to retrieve materials in small lot quantities. The task is to assemble LEGO© blocks into the form of an "airplane," initially using a continuous "push" work flow with an inspector at the end. A practice run gets the learning curve out of the way, then a production run begins. Part way through, a quality problem is announced, and the WIP is set aside as scrap and/or rework. Production resumes and then eases at the end of a timed period totalling six minutes. The resulting productivity data is collected and displayed on the chart. Completed and WIP product materials are then broken down and replaced into their storage area in preparation for the next phase.

A few changes are introduced for the second phase of the simulation. Workstations are re-arranged more closely and in a logical sequence to simulate a cellular arrangement, with all materials close to the workstations. Production is still in a "push" mode, and the quality interruption is repeated. Final inspection remains the same, but airplanes are now assembled in batches of five. At the end, data is recorded, revealing that the changes have yielded an increase in throughput, but more scrap was produced because production increased without a reduction in WIP.

The additional changes in the third simulation phase are significant. Batch lot production is changed to one-piece flow, and a "pull" system replaces the traditional "push" approach. The workers now are not to produce assemblies unless the queue for the next workstation is empty, and then they produce only one. Finally, workers are "empowered" to inspect their own work. In this way the quality is inspected several times as it progresses, rather than at the end. Observed results from this run will be that throughput increases further, but more importantly WIP and scrap decrease substantially.

The fourth and final phase introduces a more flexible cell workforce that is, in part, retrained to handle multiple tasks that are assigned to reduce the differences in workload of each person, thus providing a "balanced cell." Production throughput increases even further, with a stable WIP and further reduced scrap.

RESULTS

The data shown in Figures 2 and 3 typify the results of this simulation exercise. They clearly illustrate the limitations of the traditional layout and push flow in contrast with the benefits of the incremental changes that lead to the one-piece flow, pull system with workers who are able to share a balanced load and inspect their own output.

With only a simple, brief hands-on simulation exercise, employees (and students) learn the true impact of "world class buzzwords" in direct, quantifiable terms. The benefits derived from the changes are obvious. As desired by Santech management, employees who might otherwise be "clueless," nervous, and concerned about the changes in their company and jobs can understand the objectives and need for change. Morale at the firm is good and most employees enthusiastically accept the changes and willingly participate in implementing them. They and management became more keenly aware that (a) significant changes in the manufacturing environment are necessary and (b) that it is critical to communicate effectively to the workforce in order to reduce the risk of failure in these changes. In implementing technical change, it is essential to remember that industry is not technology: it is people using technology. Productivity gains cannot be made while ignoring the human factors. Members of upper management in industry can effectively demonstrate to their operations managers, supervisors, and hourly personnel why the status quo is unsatisfactory by utilizing methods such as the Santech simulation, and thus motivate them to accept and become proactive in implementing the necessary cultural changes in moving toward world-class competitiveness.

Mr. Deese of Santech has demonstrated the simulation exercise to participants of a small business development seminar series conducted at the ARRI (Automation and Robotics Research Institute) facility of the University of Texas/Arlington. He is also making a packaged kit including all materials and documentation available. Technology managers and technology faculty may obtain a well-developed, industry-proven tool to convey difficult "book" concepts at a reasonable cost. Information can be obtained from the author.

"Dissatisfaction with the status quo must be felt at all levels of the organization. This gives people the impetus to change. It is not sufficient for management to mandate change" (Weddle, 1994).

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3. Computer Simulation and Virtual Reality Applications in Technology Studies

by Xueshu Song

This describes a program designed to teach welding and a research project to assess its effectiveness. The discussion that follows draws implications and conclusions concerning this instructional innovation.

Welding as an industrial technology is vital to our national economy. Experts estimate that welding is involved in about 50% of the GNP (Gross National Product). More than a million people work in 60 welding-related occupations in the United States. High tech-oriented welding procedures have been introduced by industry in recent years. The many dimensions of metallurgy, physics, mechanics, chemistry, geometry, economics, management, and psychology of welding epitomize the interdisciplinary nature of state-of-the-art modern technology studies (Song, 1995a). A welding technology curriculum, either on its own or as part of the industrial technology curriculum, is taught throughout the world.

Welding activities, however, are potentially hazardous for students due to exposure to dangerous fumes, noise, and radiation and the risk of electric shock. These hazards cause concern among students. Institutions have to take extra safety measures because most students have no experience with these processes. Most educational institutions do not possess electronic beam welding, laser welding, or explosive welding equipment because of monetary and safety constraints. There is a consensus among government, industry, and the education communities that it is imperative to find more effective, more efficient, safer, and less costly ways of educating and training the workforce in the welding industry (Song, 1995a).

The recently completed Welding Lab on Disk (WLOD) project (Song, 1996) was a further development of the WLOD system based on the original modules conceived and developed by Song (1991). The primary objectives of the project were to develop, field-test, and promote the WLOD, a sophisticated interactive computer software system simulating 10 welding processes that are most frequently used in industry.

ABOUT WLOD AND HOW IT WORKS

WLOD has high resolution graphics, an interactive, user-sensitive interface, and an adaptive-testing mechanism. Peer-competition mechanism and control parameters are simulated for different welding processes in both analytical mode, illustrating engineering fundamentals, and synthesized mode, providing the virtual realities of the welding processes (Song, 1996).

Synthesized Modules (e.g., Gas Tungsten Arc Welding)

The synthesized module simulates the movement of the electrode controlled by the mouse, and the welding parameters are adjusted through a graphic button panel. Simulated process parameters are as follows: current polarity, current intensity, arc length, welding gun travel speed, filler feeding and withdrawal, base metal thickness, type of base metal material, electrode type, electrode diameter, filler material, filler diameter, and the chemical composition of the shielding gas. Welding zones are depicted with both orthographic projection and pictorial views. The system gives a performance achievement score each time the user practices with the synthesized module. The score is based on the user's choice of welding parameters, which affects the metallurgical quality of the weld. The kinematics of the mouse movement controlled by the user determines the geometric quality of the weld. Since different users may obtain different scores, a peer pressure and competition mechanism takes place.

Analytical Modules (e.g., Shielded Metal Arc Welding)

The analytical modules reveal the physics, chemistry, mathematics, and other sciences of welding. The analytical module shows the polarity simulation under welding physics, where pixels of different colors represent ions and electrons, respectively, their direction of movement being illustrated through animation. Impacts of polarity on penetration and build-up are revealed with different melting rates represented by the speed of the proliferation of red and yellow pixels in the welding zone. Welding physics also includes simulation of the melting rate as a function of material heat capacity, heat conductivity, specific heat, and power input to the welding zone. Under welding mathematics, the definitions of weld geometry, welding geometry, and joint geometry are defined and illustrated with animated graphic images. Welding chemistry, welding safety, and welding equipment are also included.

Symbolic Menu System (e.g., Electron Beam Welding)

An F-16 fighter in the background constitutes a symbolic menu. Clicking on the cockpit will produce the lab that provides the eye-hand coordination training. The engine represents the fundamental level, where the math, physics, chemistry, metallurgy, and other scientific principles of welding are simulated. The right-hand missile carries the quiz, while the left-hand missile launches the safety module. The rudder provides help and the afterburner nozzle indicates the quit button. This graphic menu system is carefully designed to attract young people to learn welding engineering technology.

RESULTS OF A FIELD TEST

Field test participants included 61 college and high school students and 30 welding teachers as well as representatives from industry and government agencies. Participants were divided into two groups: a WLOD group that used the WLOD system and the non-WLOD group that did not use the WLOD system (Song, 1996).

Improved Attitude

Pre and posttests were designed to measure the students' change of attitude before and after using the WLOD. Variables included students' attitude toward welding, computer simulation, computer programming, mathematics, physics, chemistry, science, engineering, and advanced technology. A score of 5 was assigned to "Strongly Agree," 4 for "Agree," 3 for "No Opinion," 2 for "Disagree," and 1 for "Strongly Disagree."

For the 61 participants of the field test, the mean score difference between pre and posttests for the WLOD group was 0.5525, or a change of 14.73%, based on the pretest mean score. The mean score difference between the pre and the posttests of the non-WLOD group was -0.0125, or a change of -0.334%, based on the pretest mean score. The difference between changes of attitude scores of the two groups was 0.5650. The *t* test showed that a 95% confidence interval of this difference was (0.0305, 0.8250) at a significance level of $p < 0.0001$.

Similar pre and posttests were designed to measure the teachers' attitudes toward effectiveness of computer simulation in teaching, welding, science, and advanced technology. The mean score from the pretest was 3.420 and the mean score from the posttest was 3.807. An increase of 11.3% was shown based on the pretest mean score. The *t* test showed that the difference between the means of the pretest and the posttest was within a 95% confidence interval of (.235, .538) at a significance level of $p < 0.00001$.

Increased Test Scores

Questions were designed to measure the students' knowledge of all the 10 welding processes that the WLOD simulates and related math and scientific fundamentals. A score of 1 was assigned to each correct answer.

For all 61 participants of the field test, the mean score difference between pre and posttests for the WLOD group was 20.40, or a change of 102.0%, based on the pretest mean score. The mean score difference between the pre and the posttests of the non-WLOD group was 5.20, or a change of 26.0%, based on the pretest mean score. The difference between the changes in the knowledge scores of the two groups was 15.20. The *t* test showed that the 95% confidence interval of this difference was (10.10, 20.20) at a significance level of $p < 0.0002$.

Reduced Lab Time Needed to Complete a Satisfactory Weld

For both the WLOD group and non-WLOD group, the time, in minutes, needed to complete a satisfactory weld was recorded. Since each participant in each group completed two welds, scores were combined and the average time needed to complete one weld was used in analysis.

For the 61 participants in the field test, the mean time for the WLOD group was 37.3 minutes per weld, while the mean time for the non-WLOD group was 52.9 minutes. By using the WLOD, weld time was reduced by 29.48%, based on the mean time needed for the non-WLOD group. The difference between the mean time needed by the two groups was 15.6 minutes per weld. The *t* test showed that this difference was contained in a 95% confidence interval of (9.30, 21.90) at a significance level of $p < 0.00001$.

Lab Updating Cost and Salvage Value

As compared with actual equipment upgrading and lab personnel retraining, the updating of the WLOD is much less costly because the software system can be easily updated electronically. When physical depreciation of the computers is ignored, the WLOD has a full salvage value, since the cost for a new CD-ROM is nominal when compared with the cost of updating actual equipment needed for 10 different welding processes. Moreover, the actual welding equipment usually has much less salvage value at upgrading, as compared with the initial expenditure. This low cost advantage of the WLOD is especially significant because today's accelerated technological changes in welding processes and equipment require more frequent, responsive, and efficient updating of teachers' and students' welding knowledge.

WLOD IN EDUCATION

Virtual Technology Laboratory

The cost of using sophisticated scientific modeling in engineering research is usually significantly less than experiential procedures (Song, 1995b). The same can be said of technology studies. In general, many technology lab procedures can be costly and hazardous, and some technology principles can simply not be demonstrated in the lab at all. When an environmental issue is involved such as when some lab materials and processes are contaminative to the environment, simulation and VR can reduce or eliminate the use of such materials or processes with a direct positive impact on environmental problems. Simulation and VR can also be used in regulating students during ergonomic procedures to enhance safety. One logical extension of the WLOD research is to enlarge the knowledge domain leading to more virtual technology laboratories.

A recent study based on a statistical analysis of 10,212 observations of student evaluations of technology teaching accumulated from 1986 to 1992 has shown that class size is inversely proportional to the student rating of teaching quality (Song & Li, 1993). Virtual technology laboratories can be highly flexible to any individual student since they reduce class size to a minimum with a one-to-one relationship between student and teacher (i.e., the computer). The added adaptive testing system can automatically diagnose the student's progress and set the adapted level of intellectual challenge and speed of learning. This idea can be further extended to the concept of a flexible education system.

Flexible Education System

Modern flexible manufacturing systems began in the early 1970s to meet the competitive challenge of the world economy for frequent updating of products and high production rates. Such systems maintain both mass production productivity and blacksmith workshop flexibility, two fundamental necessities for adapting to the rapidly changing marketplace. Today's technology educators are confronted with similar challenges of those faced by manufacturing industries in the early 1970s. Because careers are changing faster and with a higher degree of unpredictability than ever before, technology curriculums must be designed with maximum flexibility to adapt to the changing world, its post-industrial economy, and its labor markets.

While the necessity for a modern flexible education system is evident, the feasibility of designing and implementing such a system lies in the conceptual structure of a flexible education system, which is analogous to the modern flexible manufacturing system in the combination of educational group technology (Song & Li, 1994) and computer simulation and VR. The initial cost for developing and implementing the computer-integrated education systems can be reduced through the concept of recursive education.

Recursive Education System

Certain natural laws have been seen to apply recursively at different scales and in different disciplines. In computer programming, a function defined partially by calling itself a function is called recursive programming. Similarly, in recursive education, students are involved not only as users but also as definers or developers of subsets of software packages similar to the WLOD. The feasibility of combining students' roles as both users and developers has been studied (Song & Stoia, 1993). This combination of the user and developer roles has potential not only to foster positive attitudes of students as users from a sociopsychological point of view, but also enhances the information reproduction rate in modern technology education from the educational economy perspectives.

History tells us that scientific fantasy leads to engineering and technological reality. Aristotle, quoting Plato, asserted that philosophy begins with awe. "We may generalize further and say that all true learning begins with wonder" (Schindler, 1991). Schindler pointed out that the first task of a "teacher is to romance the students: to excite their curiosity and awe." But how? "...in any way that is legal," Schindler continued. Computer simulation and VR are definitely two of the ways that are both legal and exciting.

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4. Universal Performance Behaviors: What Ought to Be in the Technologist's Toolkit

by John W. Sinn

This is the second in a series of three IDEAS articles on development and application of a conceptual model. The first article, identified in the author's note, described the model and the underlying rationale that guided its development. The current article, the second in the series, articulates and identifies behaviors that ought to be part of the array of competencies, or behaviors, of all technologists, regardless of their specific professional assignment.

If the profession accepts the notion that there is, indeed, a common set of behaviors, then it follows that the core skills and knowledge that are appropriate to preparing technologists and the instructional and learning arrangements that will ensure that these happen ought to be considered by the profession. The third article, which will be published in this journal's Winter/Spring 1998 issue, will provide content recommendations and learning instruction strategies for education and training programs based on the considerations of the common behaviors. **JS**

Although this article can stand alone, it should be read in conjunction with a companion piece, "Building a Model for Technology Studies," which appeared in the Journal's Volume 22, Number 2, Summer/Fall 1996 issue. The model discussed in that article has undergone revision based upon reader, client, and user feedback. Changes based on these inputs are reflected here. The model was originally conceived to guide the work of the Center for Quality, Measurement, and Automation (CQMA) in the College of Technology at Bowling Green State University (BGSU). CQMA experiences with a number of technology transfer projects for business and industrial clients have contributed much to the refinement of the model. Also, participation in the development of an Applied Quality Science bachelor's degree program further tested, refined, and demonstrated the efficacy of the model as did more recent experiences with a research project conducted for the American Society for Quality Control (ASQC) to define core knowledge for technologists. Details and reports of these experiences may be obtained from the author.

This article is about first considerations that lead to suggestions for instruction and learning in traditional and nontraditional circumstances. It enumerates and describes behaviors that are universal or common to all technologist functions. Based upon these behaviors, the technologist's toolkit of core content and skills is derived.

Universal Technologist Behaviors

Several behaviors can be identified as common or universal to technologist performance regardless of an individual's specific industrial responsibilities or technology focus.

Technologists are team builders, problem solvers, and technical managers and leaders. Three technological behaviors of (a) data, analysis; (b) documentation, assessment; and (c) synchronous leadership, action are components of broader problem-solving behaviors. These focused technological behaviors are shown in Figure 1. The overlap of the circles implies interaction and synergy of the behaviors for team building, problem solving, and improvement.

The phases of assessment, analysis, and action displayed in Figure 2 provide part of the base for problem solving. These take place within a broader infrastructural context created by the three primary behaviors in Figure 1 and are related to feedback for successful problem solving. While shown as a linear activity, the functions are not always discreet, straightforward, and simplistic. Yet the relationships suggest a useful strategy for bringing forward technical solutions and improvements.

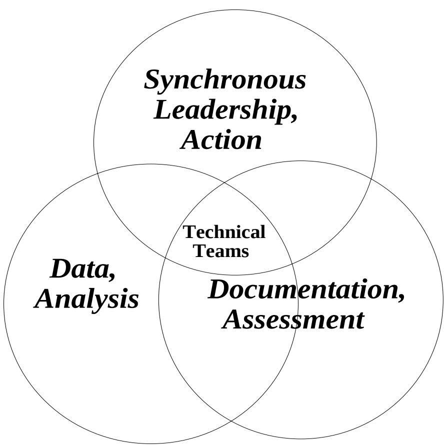

Figure 1. **Relationships of universal technological behaviors.**

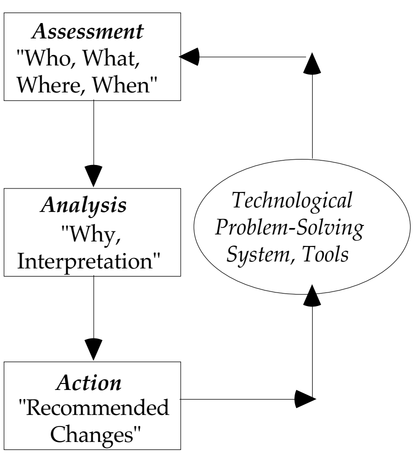

Figure 2. **Assessment, analysis, and action behaviors in the problem-solving context.**

Documentation, Assessment

Figure 3 displays the documentation and assessment phase in problem solving. During the assessment phase of problem solving, technologists and others on the team must document circumstances that suggest opportunities for improvement. These may include demographic data such as persons and equipment involved as well as process flow charts of macro and micro processes. Much documentation will be involved to "flush out" the "who, what, where, and when" about the way things are currently done. If this were a total line or production job site, layouts, time and cost data, standard operating procedures, and flow charts on the current process and system would be required at either the micro or macro work levels. Product design and specifications documentation would also be a part of the assessment. Various tools for data analysis and documentation would be formulated in relation to the nature of the product and process. Data and documentation tools selected and used in the assessment phase will have a direct relationship to overall outcomes for both immediate problem solution and subsequent phases. This suggests that most technical problems will require several iterations and input from many different persons, functions, and levels, and certainly multiple tools for solution.

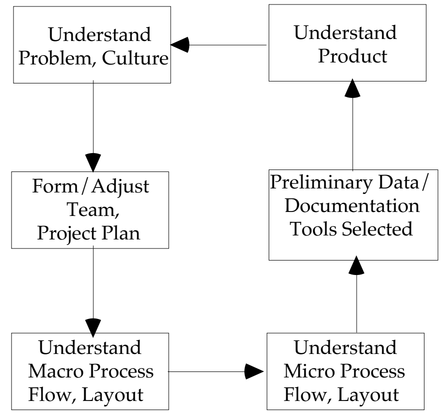

Figure 3. **Documentation and assessment behaviors.**

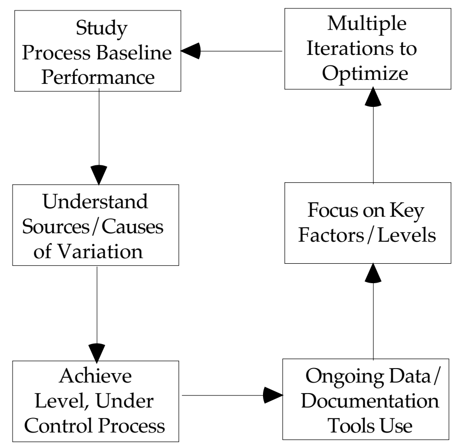

Figure 4. **Data and analysis function behaviors.**

Data, Analysis

While the major focus for assessment is to determine the current methods for processing a product, data and analysis functions build on and around the assessment. The data and analysis functions, as technological behaviors, are also pivotal phases of the problem-solving process. Data and documentation begun as assessment phases are fine tuned, and multiple iterations may be required based on further analysis. Ultimately, various experiments or trials may be run to determine optimum conditions or to further analyze what was believed to be valid in the original assessment. In the analysis phase it is also important to establish data and documentation as performance baselines upon which to base measures of improvement. Baselines allow sources of variation to be identified and studied further with a view toward eventual optimization. Stabilization in process must be achieved in reasonable ways, facilitating a clearer understanding of broader relationships in production processes. As this occurs, factors and levels appropriate for further study will begin to surface. This assumes that under control conditions a sufficient analytical environment to demonstrate optimum conditions in process can be facilitated. The expectation is for a technologist to guide cross-functional team processes to generate and analyze data as shown in Figure 4. This represents another basic set of behaviors that are common or universal to technologists in their practice regardless of venue.

Conflicting views or information that emerge in the assessment may require various analytic tools to be applied to achieve clarification. Tools at this phase may cover such basic data as attribute and variable charts, gage repeatability and reproducability (R & R), and capability (Cpk). These statistical indices would be organized within the ongoing process control plan (OPCP) and failure mode and effects analysis (FMEA) documentation tools. More than likely, in most cases only one or two of the tools will be used. But the array of tools available for analysis should not be underrepresented. Likewise, the number of iterations with any one tool, to continue to interpret and understand the overall problem circumstance for improvement, will vary. The quality of the problem solution, and overall robustness, will determine the number of iterations that need to occur. This implies important technologist roles and relationships as a data analyst.

Synchronous Leader, Action

The final phase in a problem solution includes recommendations in the form of leadership and action, an important component of the professional development of the technologist. Actions may consist of new procedures to be followed, new equipment to be procured based on conclusions that processes analyzed were not capable, or others. This will drive the establishment of new standards, training approaches, and perhaps other studies. For example, if it is determined that new equipment is needed to implement a solution and improvement, new studies and iterations will likely be required. This is what ongoing improvement is about, of course, as depicted in Figure 5. It would be quite common, for example, to determine that additional training is required or better gaging is needed, or to identify shifts from one characteristic to another. Unquestionably, however, the costs of such actions will need to be detailed and presented with justifications for changes, and improvements brought forward.

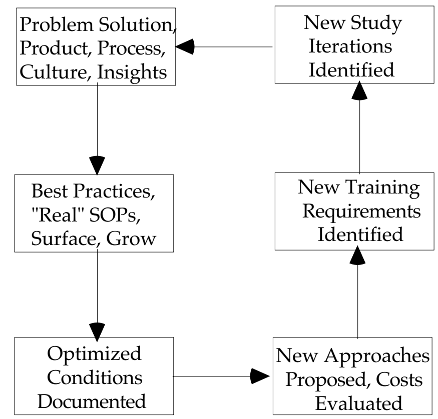

***Figure 5.* Ongoing improvement systems result from technologists' leadership behaviors.**

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5. Teachers' Attitudes Toward Computer Use

by Sherry Hill Howie and Jia-Rong Wen

In recent years global demands for knowledge about and application of technology have greatly impacted educators. However, research shows a resistance of teachers to new innovations that affects their levels of usage and stages of concern (Hall, 1977; Kluever, 1992). Because technology in education is an innovation that impacts education, it is valuable to assess teachers' attitudes as they learn and adapt to changes in technology. A cross-cultural comparison of teachers' attitudes may lend more insight into areas affecting attitudes. By learning about teachers' attitudes toward using computers in education, teacher training may be planned better to address concerns and needs of teachers as they learn about technology.

For this purpose, we compared teachers in the Republic of China (ROC) and the United States in their attitudes toward using computers in teaching. We also sought information on the degree to which middle school teachers have accepted computers. Cultural and other differences prompted us to expect a significant difference in attitudes between the two groups of middle school teachers we surveyed, which included junior high school teachers of Taiwan, ROC, and San Bernardino County Schools, California—the latter group being surveyed six months after the first group. Taiwan geographically is 14,000 square miles in size with 716 junior high schools, while San Bernardino County is 20,000 square miles (largest county in the USA) with 37 school districts and 66 junior high/middle schools. For the survey in Taiwan, 100 out of 716 junior high schools (from the seventh to ninth grade) were selected by random sampling. Each of the 100 schools received five surveys for principals to distribute to teachers. Of the 500 surveys, 412 were returned, yielding a response rate of 82.4%.

For the survey in San Bernardino County, 66 middle schools were selected at the same time, each receiving 10 copies of the questionnaire. Of the 660 questionnaires sent, 203 were returned, which resulted in a response rate of 30.7%. The total number of surveys returned for both Taiwan and San Bernardino was 615.

The authors designed the questionnaire. The three psychological areas that affect attitudes are reflected in the survey questions. These areas, adapted from the research of Gardner (1993), Kluever (1994), and Massoud (1991), measure fondness for, confidence in, and perceptions of usefulness of computers in education. The questionnaire used 15 questions and a Likert scale of five options: Strongly Agree, Agree, Not Sure, Not Agree, and Strongly Disagree.

BACKGROUND

The Ministry of Education for the ROC of Taiwan started to infuse computer-assisted instruction (CAI) into education more than 20 years ago. Today, more than 4,000 teachers have been trained, and they have developed thousands of CAI materials that have been sent to every school of every level for teachers to use as teaching aids. However, despite much effort, including two Six-Year Plans for infusing CAI and training teachers, very few Chinese teachers used computers in teaching after 15 years of promotion (Wu, 1992).

A problem faced by Chinese teachers is using Chinese characters in a western-developed technology. The computer design follows western cultural backgrounds and living habits. Keyboards, for example, are developed by the orientation of the alphabetic order, and all the other peripheral input and output equipment are developed with consideration of English users. Thus, using advanced computer technology for input and output of Chinese characters is inconvenient. In Taiwan, the input of Chinese characters into computers is usually done by separating the character roots or using phonetic symbols. This process is difficult and slow and greatly hinders Chinese teachers' or students' willingness to use the computers. Since there are differences in cultural backgrounds and social situations between the Republic of China and the United States, the attitudes toward using computers may be different; therefore, there may also be differences in the development of computer education in each country.

In teacher training in CAI, teachers in Taiwan sign up for classes on a voluntary basis and may wait as many as four years before they are able to take classes at the regional universities where programs are administered through the ROC Ministry of Education. In contrast, in San Bernardino County, California, new teachers are required by the state to have training in computer applications to earn teaching credentials. This requirement is implemented through university teacher training programs, and continual updating is available through district and university in-services.

Other important differences lie in the fact that 50% of USA students own their own computers, according to a 1992 study by the International Association for the Evaluation of Academic Achievement, compared to less than 5% of students in Taiwan. That study, "Computers in American Schools, 1992: An Overview," also found that 99% of schools in the United States have computers. Furthermore, schools in Taiwan have only IBM machines, while schools in the United States use many different brands, some of which do not share software. Hardware in US schools tends to be older than machines in Taiwan. In contrast, Taiwan has a centralized plan to use computers in schools throughout the island, but the United States has 50 state plans with no centralized administration of a national plan. Taiwan's plans are funded by the government, but each state in the United States is funded according to the state budget. These are differences between the two societies that may influence differences in teachers' attitudes.

WHAT WE LEARNED

Our original expectation that middle school teachers of the ROC and the USA do have significant differences in their attitudes toward using computers was affirmed. The teachers of both groups have positive attitudes, but they are significantly different in the degree to which they like using computers, see usefulness of them in teaching, and have confidence in their abilities to use them. The attitudes toward using computers of teachers in the Taiwan group are not as positive as those of teachers in the USA group.

The data showed that there are two points on which teachers of Taiwan have much more positive attitudes toward using computers than teachers of the USA: (a) If they understand how to use computers, teachers of Taiwan are more eager to use them than teachers of the USA are, and (b) the Taiwanese group is more eager to research and study cooperatively with other teachers in learning about computers than teachers of the USA group.

We found that the attitudes of Taiwanese middle school teachers who graduated from universities differ significantly from Taiwanese teachers with other educational backgrounds. Teachers who graduated from universities were more positive and accepting in their attitudes than teachers from other backgrounds. Also, Taiwanese middle school teachers who graduated from different departments showed significantly different attitudes toward using computers. For example, teachers who graduated from departments of natural sciences, engineering, and education differed significantly in their more positive attitudes from teachers who graduated from other departments. Lastly, Taiwanese teachers with 5 years or less of experience had more positive and affirmative attitudes toward using computers than those with 6 or more years of experience.

The results of the analyses and comparisons for both Taiwanese and the American middle school teachers' attitudes toward using computers may be summarized as follows:

The attitudes of Taiwanese middle school teachers toward using computers change according to the following variables:

1. Teacher's age—the older teachers manifest more passive attitudes toward using computers.
2. Highest educational background—the teachers with higher degrees in educational backgrounds have more positive and affirmative attitudes toward using computers.
3. Departments they graduated from—teachers who graduated from departments of natural sciences, engineering, and education have more positive attitudes toward using computers.
4. Years of teaching experience—this may be related to age. Teachers with more than 6 years of teaching show much more negative and conservative attitudes toward using computers than teachers with 5 years or less of teaching experience.

The attitudes of the American middle school teachers toward using computers do not change according to the variables of sex, grades, courses, age, highest educational background, departments, and years of teaching experience, indicating that in the USA it is quite a common idea to use computers for everyday purposes, and people of the USA often regard using computers as a matter of course. Because of the commonness of computers, they have more positive attitudes.

Computers are the products of scientific civilization and have a close relationship to conduct of human lives. It is an inevitable trend that computers be used in teaching for better education in an information age. However, people usually need time to accommodate or adapt themselves to new innovations. The findings from the analyses and comparisons of the data (in the three psychological areas affecting attitude—fondness for using computers, perceptions of usefulness of computers, and confidence in using computers) show that teachers of the USA significantly possess more positive attitudes than teachers of Taiwan. This finding definitely impacts teacher training in both Taiwan and the USA. Teacher training courses need to address the areas of attitude identified in this study so that teachers will be helped to develop positive and constructive attitudes toward using computers.

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