A DYNAMIC APPROACH TO TECHNOLOGY TRANSFER

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ABSTRACT

Stone & Webster Engineering Corporation has developed a systematic program for achieving efficient, effective technology transfer. This program is based on transferring both know-why and know-how. The transfer of know-why and know-how is achieved most effectively by working in partnership with the recipient of the technology; by employing five primary transfer mechanisms, according to the type of learning required; by treating the technology transfer as a designed process rather than an isolated event; and by using a project management approach to control and direct the process. This paper describes the philosophy, process, and training mechanisms that have worked for Stone & Webster, as well as the project management approach needed for the most effective transfer of technology.

INTRODUCTION

Over the years, many approaches have been taken to the transfer of technology, with varying degrees of effectiveness. In the past five years, Stone & Webster Engineering Corporation (S&W) has been responsible for transferring technology to clients in six countries. Based on this experience, we have developed a technology transfer program that we believe works best.

The best approach depends on analysis of the nature of the particular activity or package of activities for which technology is being transferred and on versatility in applying five primary transfer mechanisms. The key element of a successful transfer effort is that both the know-why and know-how are transferred in an integrated manner. This implies that the donor must have a thorough understanding both of the technology being transferred and of the needs of the recipient.

Inherent in our approach is the belief that technology transfer is a designed process, not a singular event. All activities and plans developed to accomplish transfer must be conceived, designed, developed, implemented, and evaluated with this in mind. We believe the transfer donor and recipient working in partnership to design the transfer program is essential to the effectiveness of the transfer.

PHILOSOPHY OF TECHNOLOGY TRANSFER

One of the bases for our approach is that the technology transfer vendor must also be a technology transfer partner. Technology transfer is undertaken to develop a level of independence by the client organization. The commitment to this independence must be fundamental, with both organizations participating in the process, so that a partnership relationship is developed.

Inherent in this commitment is a belief that technology transfer is a process, not an event. All activities and plans for accomplishing transfer must be conceived, designed, developed, implemented, and evaluated with this in mind. Figure 1 represents the difference between the vendor and partner approaches.

Know-how and Know-why

Successful technology transfer requires a fundamental understanding of the difference between know-how and know-why. For example, in a power plant design, the know-how of taking a drawing from early preparation to issue involves a number of critical steps and decisions, such as procedures, computer programs, and vendor information. Knowledge of these steps, and how to follow them effectively, is critical to the execution of a project. With this knowledge, an engineer can perform the tasks required to support production efforts under the leadership of an experienced supervisor. The know-how transfer, therefore, consists of the transfer of the relevant references and computer codes for a particular task, training in their contents and application, and practice applications in a controlled environment, such as a classroom.

"TECHNOLOGY TRANSFER *PARTNER*: THE EXTRA STEP THAT MAKES THE DIFFERENCE."		
	Vendor Approach	*Partner Approach*
Primary Transfer Product	Know-how	Know-how and know-why integrated
Scope of Tools Transferred	Pre-developed programs and references transferred to your machines and your bookshelves	All necessary programs and references, along with ability to use and adapt if necessary
Scope of Classroom Training	Send trainees to local universities; exposed to existing courses not related to specific applications	Tailor existing training to trainee needs; direct lesson plan relevance; instructor quality. Outside resources supplement as appropriate. Develop new programs as needed to meet technology transfer requirements
Scope of On-The-Job Training	Place trainee in an available relevant work position	Place trainee in a series of job experiences designed to lead to competence
Skill Level Developed by Trainees	Ability to apply tools and knowledge to defined problems	Ability to define problems and determine appropriate actions
Depth of Transfer	Concepts and principles	Judgment and reasoning for problem definition and decision-making
Scope of Transfer	Primarily technical	Technical, management, administrative, and project
Relationship of Trainer and Trainee	Instructor/Learner	Colleague, instructor and consultant
Overall Goal	Knowledge/Awareness	Independence/Capability

Fig. 1. The vendor approach vs. the partner approach.

Know-how transfer generally assures that the trainee, given a similar problem to solve, can perform effectively.

The same engineer, however, might not be prepared to make other significant decisions about drawings independently--for example, decisions about which drawings are needed; whether a drawing can proceed without certain information; how other disciplines will impact this drawing; what computer codes to select under various conditions; or the cost or schedule implications of decisions.

To prepare the engineer to function independently requires a concerted effort to transfer more than the know-how. The know-why must also be transferred. It is the integrated transfer of both that provides the foundation for problem solving, innovation, training of others, continued self-development, and independence.

The know-why consists of the ability to define a problem and select an approach in a real world environment, such as a project. It involves understanding not only the approaches available, but also why they were developed, what they are valid for, and what they will not provide. It involves a level of judgment as to whether a situation is a problem and whether it needs to be addressed in great analytical detail. It involves the ability to factor into a decision the impact on the rest of the project, including other discipline products, vendor and contractor activities, and overall project cost and schedule.

The key element of a successful technology transfer effort is the transfer of both know-how and know-why in an integrated manner.

Technology Transfer Approach

Effective technology transfer requires more than having a well-documented and current technology base and an organizational commitment to make it work. It requires having a proven and established approach for assuring that the program meets its objectives.

The most successful technology transfer efforts have been characterized by frequent and meaningful personal interactions. Assuming the adequacy of the technology base, the relationship that develops between transfer agent and

transferee will determine the effectiveness of the transfer effort.

Part of a planned approach to technology transfer must include evidence that the personal interactions will, in fact, be effective. To help ensure this, S&W has examined the typical relationship between transfer agent and transferee. As illustrated in Figure 2, we find that this relationship is one that typically develops over time in five phases. The progress of individuals through these phases varies based on the individual's education, experience, and ability. The transfer process is improved if steps are taken to accelerate the development of this relationship.

The transfer agent has a responsibility to accelerate the relationship. This can be accomplished through a technology transfer workshop, which should take place prior to the start of the technology transfer project. This workshop allows personnel to finalize their own transfer assignment goals and objectives, to clarify their respective roles and responsibilities, and to practice transferring technology in a classroom environment before the actual contracted transfer process begins. This workshop accelerates the establishment of mutual expectations and enhances interpersonal communications.

THE PROCESS OF TECHNOLOGY TRANSFER

The goal of technology transfer is to effectively transfer know-how and know-why of the technical, administrative, and project-related functions and activities. There are some basic premises and objectives from which the process of technology transfer has been developed.

Premises

- Know-how and know-why are inextricably linked when operating in a team environment. The acquisition of the ability and the ability to function as a professional requires that know-how and know-why be transferred together as one entity.

- Credible transfer of this technology can be achieved only if it is carried out in a systematic and orderly fashion.

- Effective transfer cannot take place if those engaged in "active" project work are totally responsible for the transfer process.

PHASES OVER TIME				
I	II	III	IV	V
INSTRUCTOR				
Provides Information — Takes Full Responsibility For Education Of Trainee — Adheres Strictly To Lesson Plan	Presents Information And Invites Comments — Adheres to Lesson Plans And Course Design	Presents Problem And Invites Help In Definition Or Approach — Provides Information Trainee Needs To Define And Solve Problem — May Change Plan To Meet Trainee Needs	Presents Situation And Acts As Facilitator And Consultant To Trainee — Gives Trainee Information Requested And Coaches Him	Acts As Consultant And Colleague
TRAINEE				
Passive Learner — Listens, Takes Notes	Asks For Clarification And Repetition When Necessary	Actively Asks Questions To Bridge Gaps Between His Experience And Understanding — May Question Problem Definition Or Approach Used Thereby Exercising His Own Reasoning And Initiative	Defines Problem And Approach — Defines Knowledge And Information Needed To Solve Problems — Solves Problems And Receives Instructor Feedback	Able to Completely Define Information Needs — Functions Independently In Most Cases — Requests Feedback From Instructor

Fig. 2. Phases in the development of the instructor/trainee relationship.

- A project management approach is required if a cost-effective project is to be achieved.

Objectives

- Define know-how and know-why technology transfer.
- Design an effective system to transfer know-how and know-why in an integrated manner.
- Apply this system to progressively train and develop the candidates, in a systematic and orderly fashion, in the specific technology. A variety of specially conceived educational techniques called "transfer mechanisms" are used that develop functionally qualified individuals who have demonstrated their abilities to operate in a team environment and who are skilled in the application of appropriate technologies on an integrated basis.
- Manage the technology transfer program in a cost-effective manner.

Process

An effective process of technology transfer consists of:

- Program definition
- Job function analysis
- Systematic program approach
- Program management
- Performance measurement

Program Definition. One of the first activities of any technology transfer program is to develop a clear understanding between the two parties of the nature of the transfer. This discussion includes the definitions of both the know-how and know-why required. Agreement on these definitions and the specific objectives of the program must be accomplished and established as a part of the program execution plan.

The program execution plan is developed as an initial program activity and includes the scope of the program activities, the work breakdown structure, schedule, and budgeted man-hour estimates. It presents the basic methodology of how the program will be accomplished. It includes the mechanisms of technology transfer, the systematic approach to training that will be utilized, and the program management tools and techniques used to control the program.

Job Function Analysis. If the technology transfer program is to be performance-based, there must be an analysis of the tasks to be performed and the requirements of the individuals needed to perform the job. The results of such an analysis clearly identify the needs of the technology transfer program. This effort is best conducted jointly by the two parties involved in the transfer.

Systematic Program Approach. An essential ingredient of a successful technology transfer program is the use of a systematic approach. The characteristics of this approach include a careful analysis of what and how the trainees will learn and how the transfer process will be evaluated.

What will be learned should be based on carefully stated learning objectives focused on that knowledge, skill, or attitude required for adequate on-the-job performance.

How participants will learn should be based on carefully designed transfer mechanisms that are learner-centered and focus on the learning objectives. These transfer mechanisms include:

- Classroom training
- On-the-job training
- Simulation workshops
- Switchover of responsibility on actual projects

The true determination of the effectiveness of the process is whether the learner can effectively carry out the responsibilities of the trainer or instructor on an actual project.

What and how participants learn must be evaluated against the objectives of the program. This must be done by providing opportunities for individual feedback at periodic intervals during the transfer process.

The section of this paper entitled "Training Mechanisms" gives a specific description of the process used to develop training programs. Figure 3 illustrates this systematic approach. This includes analysis, learning objective development, training program design, implementation, and evaluation of both the participant and the technology transfer program.

Program Management. Of equal importance to compatible philosophies and project approach is the efficient management of the program and its execution.

It is our philosophy to utilize effective project control procedures in the execution of all our work. S&W applies this philosophy to our technology transfer programs.

A technology transfer program has many discrete activities that must be performed in time to meet assignment schedules of the

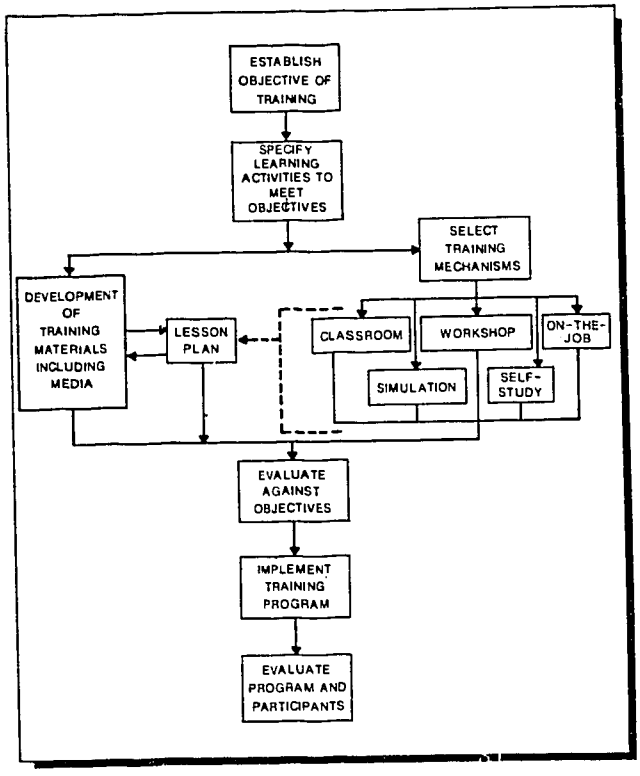

Fig. 3. A systematic approach to training satisfies program objectives.

candidates to ongoing and proposed client projects. In the transfer of know-how and know-why technology, as described previously, numerous important interrelationships and interfaces must be recognized and documented. Credible plans to meet the proposed assignment dates of candidates require the use of network-based technology.

A large technology transfer program involves many hundreds of interrelated tasks with specific schedule dates and resource loading requirements for specific senior level personnel. The comprehensive nature of such a program requires that performance be measured regularly. Performance measurement must be applied not only to determine the effectiveness of the technology transfer, but also to measure the overall efficiency of the program execution from a cost and schedule viewpoint.

Performance Measurement. The effectiveness of any training or technology transfer process should be measured with respect to the pre-established objectives for both the program module and the participant. The unique nature of the technology transfer process makes it very difficult to measure the acquisition of know-how and know-why skills in a quantitative manner. The most effective way to evaluate performance of technology transfer activities is qualitatively, through providing performance feedback in the following ways:

- Individual discussion between the participant and the instructor to assess individual knowledge and skill level
- Written feedback from the instructor to the participant
- Group critiques of classroom training or on-the-job training modules to assess whether the module met the pre-established objectives
- Self-evaluation of individual capability to perform the functions on the various project assignments followed up by the instructor to determine the completeness and accuracy of the feedback

These steps, coupled with the evaluation of the effectiveness of the technology transfer itself, will provide an evaluation of the overall program.

TRAINING MECHANISMS

Successful implementation of a technology transfer program is based on the skills of the instructors in the subject matter, as well as their skills in the analysis, design, development, implementation, and evaluation of the training to be performed. The process of training program design and development includes a systematic approach to selection of the appropriate training mechanisms. These training mechanisms include:

- Classroom training
- Formal on-the-job training
- Workshops
- Simulation
- Self-study

A systematic approach to training specifies the learning objectives for each training module, the focus of the module design, development, and implementation of these objectives. This systematic approach is illustrated in Figure 3. Using this process assures that the training mechanisms are appropriately integrated with the learning activities, materials, and media.

Selection of appropriate training mechanisms to meet specified learning objectives is integrally related to the premise that effective technology transfer involves both know-how and know-why. For example, classroom training may be effective in meeting certain know-how objectives, but formal on-the-job training may

be a more appropriate and effective mechanism to meet the know-why objectives.

Description of Training Mechanisms

Training mechanisms are defined by the instructional setting in which the learning takes place. This instructional environment is selected based on the systems approach so that methods meet learning objectives. For example, a classroom is not the appropriate environment for meeting an objective that requires "hands-on" training. Figure 4 describes some of the considerations used to select appropriate instructional settings.

Classroom Training. This type of instructional setting is one in which the maximum number of participants can be scheduled to receive training at the same time. When it is designed to meet the appropriate course objectives, it can be interactive and learner-centered, providing an efficient mechanism to provide know-how and some know-why to participants.

Workshop/Discussion. This instructional setting is used when there is a substantial amount of interaction required among the workshop participants. It is a form of classroom training which may be oriented towards either case studies or problems and in which the instructor provides some basic guidance. The participants spend a substantial period of time as a team/group in decision making or problem solving. For example, if the training subject is conceptual plant layout and arrangement and the basic team principles have been discussed, an appropriate team workshop activity is to sketch a plant layout based on certain criteria or to evaluate an existing plant arrangement.

On-The-Job Training. Classroom and workshop educational settings serve as a basis for transferring knowledge and some skills. For complex technology, including nuclear plant

INSTRUCTIONAL SETTING	*SOME REASONS TO USE*	*SOME REASONS NOT TO USE*
Classroom	Large group of trainees can be scheduled at the same time	Hands-on environment is required for mastery
	Large amount of information is to be presented	
Workshop Instruction	Hands-on environment required *and* necessary conditions can be provided in the workshop	Necessary conditions *cannot* be provided/simulated in the workshop
Formal On-The-Job Training	Hands-on environment required *and* necessary conditions/equipment operation can be provided in the workplace	Necessary conditions *cannot* be provided/simulated in the workplace
	Sufficient qualified personnel are available to conduct and monitor the On-The-Job Training	Appropriate workplace not available or experienced personnel not available
Simulation	Strict attention to the job task is required to allow mastery	Necessary conditions can be provided in a less costly setting such as On-The-Job Training or self study
Self-Study	All conditions can be contained in the training material or made available	Close supervision required
		Task is identified as difficult to learn/perform

Fig. 4. Careful selection of training mechanisms is necessary for a successful training program.

design and construction, formal on-the-job training is a necessary and vital part of the process. It is during this phase that the application of the technology and the process of performing project activities can be demonstrated through interaction with an experienced engineer while performing the work.

Simulation. Simulation is an educational setting in which projects are created which most nearly simulate the actual work environment. Processes are used to identify the primary decisions that must be made at various times within the project schedule. Specific cases or problems are analyzed that represent or simulate real situations. This technique can be used in a workshop environment with teams assuming the roles of project personnel. This technique also has been used very successfully for nuclear plant operator training to simulate station operations.

Self-Study Programs. In many cases, self-study materials are the best mechanisms for gaining additional skills or knowledge in a particular subject. The self-study materials can be textbooks, workbooks, or computer-based aids coupled with audio or video media. The use of this material is best determined by the individual needs of the trainees.

Experience. S&W has substantial experience using all of the training mechanisms described above. Technology transfer is a recognized part of the process of our doing business. We have found from experience that the best results occur from a systematic approach that combines different mechanisms. For example, we have provided a large group of young engineers with classroom training in the fundamentals of fluid system design. This is followed by calculation workshops in which teams perform system design, followed by assignment to project activities where on-the-job training is the training mechanism.

Project Simulation Workshop. A particularly successful approach used by S&W has been the project simulation workshop. This workshop approach uses the simulation technique to address the major activities that are critical by discipline, and assumes the role of that group to complete various project activities. Each team is assigned an experienced Lead Engineer to guide the team. Every major phase of a nuclear project is simulated to provide the participant with an excellent understanding of project work. This approach has been successfully used for both internal and international client technology transfer.

PROJECT MANAGEMENT PROCESS

The technology transfer project should be organized, planned, executed, and controlled using a traditional project management approach. This should include a project execution plan, work breakdown structure, detailed project schedule and budget integrated to allow for monitoring, and control of cost and schedule to meet the technology transfer objectives.

SUMMARY

Our experience with many technology transfer efforts leads us to conclude that the most effective technology transfer is based on the following:

- Transfer of both know-why and know-how in an integrated manner
- A designed process which emphasizes the partnership approach
- A systematic program approach including objectives, lesson plans, evaluation, and a variety of training mechanisms
- A cost-effective project management approach