

Technology Transfer: The Design, Development and Implementation of a Process

Rebecca L. Smith

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Rebecca L. Smith

Written during Tenure as:
Manager, Technology Transfer Section
Hewlett-Packard Co.
Cupertino, CA

***Abstract:** From 1984 through 1989 Hewlett-Packard Company's R&D entities in the Networked Systems Sector (Cupertino) engaged in the systematic implementation of software engineering processes, methods, and tools. The goal: improve software products delivered to HP customers. This effort, led by the Technology Transfer section (TX), resulted in improvements for several projects in the areas of time-to-market, product quality, and reduced development costs. This paper presents a summary of TX's approach to the design, development, and implementation of a technology transfer process.*

1. Introduction

In 1985 Hewlett-Packard Company chartered its Software Engineering Operation (SEO) in Corporate Engineering to improve HP's software quality and productivity through the acquisition and implementation of management and engineer education programs. The SEO enlightened HP's top executives regarding the necessity and value of a disciplined approach to software engineering, a rapidly evolving field where a computer science graduate becomes technically obsolete only 2 _ years after graduating from a 4 year program; furthermore, computer science graduates are often unprepared to immediately begin software engineering.

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Putting that management commitment into action within the operating entities became the responsibility of local consulting and education teams such as the Technology Transfer section (TX). To date, HP's software R&D entities in the Networked Systems Sector (NSS; Cupertino) have received the most comprehensive, integrated software engineering processes, methods, and tools program available in the company. This paper provides an overview of the design, development, and implementation of TX's technology transfer process.

2. The Evolution of TX

In the Beginning, TX was originally a six-person team within the Quality Department that served one of HP's systems divisions. When the company recognized the need to dedicate resources to the design and development of software engineering tools for its internal systems software developers, the TX team was integrated into a lab that was created to meet that purpose. TX was chartered to develop and implement effective processes for instituting effective software engineering processes, methods, and tools throughout the R&D labs of NSS.

Initially, TX only delivered classes that were developed by SEO. That approach admittedly increased the awareness of a few engineers with regard to generic software engineering methods, but the application of those methods was not systematic. And because no managers were involved in that activity, middle managers had difficulty perceiving the value of a disciplined approach to software engineering.

In a related effort, which also proved counterproductive, many labs chose to install in-house and/or external Computer Aided Software Engineering (CASE) tools in an effort to improve their development processes. Unfortunately, the actual software development processes employed in some of those labs had not been articulated, and the selection of methods was uninformed. Furthermore, the tools that supported specific software engineering methods and processes were not adequately examined prior to their installation. As a result, some of those tools were met with outright rejection, and some managers were discouraged from further considering a non-traditional approach to software development.

1985. In 1985, the standard method of internal technical "training" still involved selecting one or two engineers from a project team and sending them to a class to gain knowledge and skills involving methods, processes, or tools. Those engineers, in turn, would be expected to impart that training to their fellow engineers and managers, a woefully ineffective process.

We in TX readily recognized that if TX was going to generate any real change in the process by which software was developed, we had to work closely with first and middle-managers and their

teams of engineers. In developing that approach, we began to create programs that addressed the needs of both the managers and their teams, treating them as “intact work groups.” Our TX team used a two-prong approach:

1. Empower the R&D teams to properly select and implement software engineering methods.
2. Demonstrate to middle-managers the value, or return on investment, that resulted from the time they took to implement the software methods and tools.

Over time, this deliberate, systematic integration of software engineering processes, methods, and tools produced tangible results that demonstrated to line managers the value of software engineering. Those results realized by the few courageous intact work groups of “early adopters”, encouraged other managers to consider changing the manner in which their teams perform work.

1985/86. During this period, another factor increased the demand for a coherent, technical education program: the development of Hewlett-Packard’s Precision Architecture (HP-PA) Reduced Instruction Set Computing (RISC). HP’s move to RISC involved new hardware technologies, new software optimization algorithms, and a host of innovative changes in operating system principles.

TX effectively met the demand for HP-PA engineering knowledge and skills. In collaboration with the people who were creating this technology, we provided thousands of engineers and managers with HP-PA courses that were focused, timely, and effective. That increase in expertise helped Hewlett-Packard to successfully meet the challenge of developing and implementing HP-PA technology. TX responded quickly to the demands of labs who wanted technical knowledge and skills acquisition, thus helping to establish our credibility as a vital link in HP’s product development process.

This credibility was accompanied by an expansion of our technology transfer services. Along with classroom training, we began to offer process consulting as well as software engineering tools implementation and on-line support. Managers recognized the expertise available in our team of software engineering consultants, and they began to demand TX services.

1986. TX became entirely self-funded, managed as an internal business.

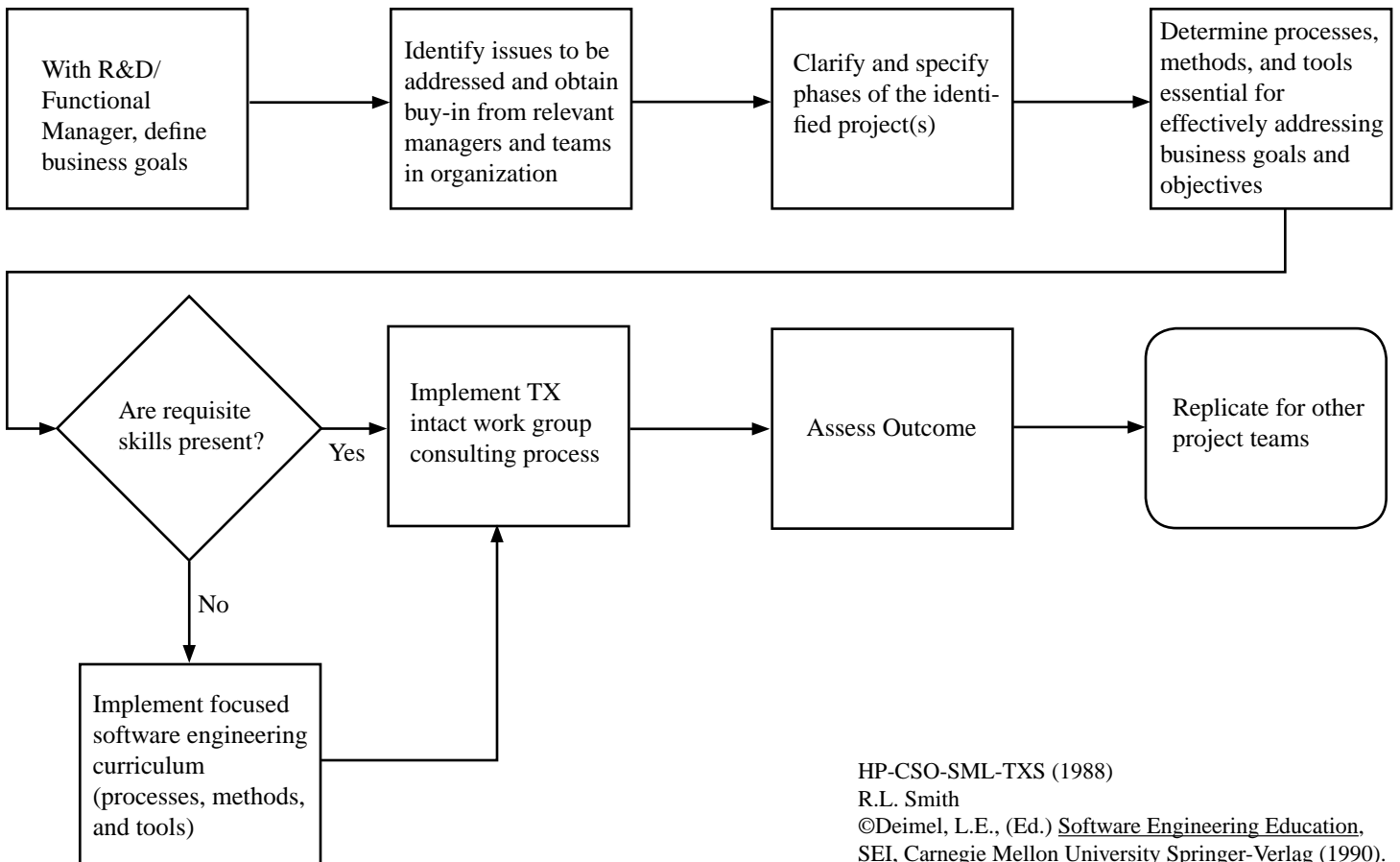
Today. We continue to generate operating revenue by delivering the myriad TX programs.

3. The TX Model

Because we manage TX as an internal business, we must work closely with our “customers”, the R&D management teams. The role of TX has changed, from simply delivering technical management and engineering classes, to providing organization-focused technology education, accompanied by the essential follow-up consulting for the intact R&D teams. We have evolved into a team of “engineer/consultants”, engineers with advanced degrees in computer science and statistics.

As our process evolved for serving engineering labs, we developed a model of our activities. Figure 1 provides a high-level overview of the components of the TX model.

Figure 1. TXS Technology Transfer Process



HP-CSO-SML-TXS (1988)
R.L. Smith
©Deimel, L.E., (Ed.) *Software Engineering Education*,
SEI, Carnegie Mellon University Springer-Verlag (1990).

This model enables us to address the concerns of any lab with whom we work, as reflected in the individual components of the model.

- **Engineering Knowledge and Skills:** Ensure that the engineers have knowledge and skills in place for effectively developing software.
- **Technical Management Knowledge and Skills;** Ensure that the managers in that organization have the skills and knowledge they need in order to effectively manage the development of software.
- **Engineering Processes, Methods, and Tools:** Allow the development team to ensure that 1) they have a clear understanding of what their processes are, 2) they understand what methods are appropriate to use at various phases in the software development life cycle, and 3) they implement the appropriate tools in each instance.
- **Software Development Environments:** Provide the actual physical configuration for software development, enabling the lab team to effectively implement their software.
- **Consulting:** Coordinate the transfer, or actual implementation, of the above components of the TX model.

By being able to offer all of those different services to a particular lab, TX helps that lab meet their business objectives. Our integrated approach to education and consulting has enabled product development teams to improve time-to-market, reduce development costs, and improve product quality.

4. Components of TX's Technology Transfer Process

During our processing of working with our customers, the TX function must address the unique requirements of several software development labs in Cupertino. To meet this challenge most effectively, the TX staff must continuously evaluate, acquire, and demonstrate essential software engineering expertise. As our team applies this expertise throughout the customer labs, we must also empower those with whom we work to continue to implement effective engineering processes, methods, and tools after the consulting process has concluded. While addressing the above, TX treats each customer relationship uniquely, providing our client labs with the optimum design and development processes, methods, and tools for software engineering, enabling them to continuously improve their products.

- **Technical Management Knowledge and Skills;** Ensure that the managers in that organization have the skills and knowledge they need in order to effectively manage the development of software.
- **Engineering Processes, Methods, and Tools:** Allow the development team to ensure that 1) they have a clear understanding of what their processes are, 2) they understand what methods are appropriate to use at various phases in the software development life cycle, and 3) they implement the appropriate tools in each instance.
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TX Gets Involved. The technology transfer process is initiated by the first or second-level manager in an R&D lab. Often, that manager has become aware of the need to examine and improve the manner in which the R&D team pursues the tasks of software development. The manager, or managers, involved are also aware of the results that other teams have realized when they changed and improved the process, methods and implemented tools used in their software development work. The team submits a request to TX.

In response, the TX management team assigns an engineer/consultant to work with the R&D team that requested assistance. At the initial stage of this relationship, both parties work together to clarify the R&D managers' reasons, objectives, and expectations that are involved in hiring TX expertise. Our process follows the logical flow diagram shown in Figure 2 (see next page).

As we work with the manager(s) to articulate their business objectives, the TX engineer/consultant assesses the lab's ability to meet those objectives. Following are some of the basic questions that must be answered.

- Does the team possess requisite technical engineering knowledge and skills?
- Can the management team integrate essential project and process management elements into their daily work?

- Is there a clear understanding of the software engineering methods, development environments and supporting tools which will enable the team to meet its business objectives?

The following goals are met as the TX engineer/consultant works with the manager(s) and engineers of the team.

1. Define and improve the software engineering processes, as they are implemented.
2. Ensure that the lab engineers possess critical technical skills.
3. Identify and teach the most appropriate software engineering methods for that team's particular product development phase.
4. Assist the team in its implementation of internal or externally available software engineering tools that support the development process.

5. Delivery Mechanisms

As we move through the steps of the technology transfer process with a lab's management team, TX delivers focused curricula and consulting process plans that enable the lab to most effectively evaluate, change, and improve the manner in which they are developing their software products. We draw on the TX resources shown in Figure 3 (see next page) to create the most effective program for each client lab. By providing an integrated program of the knowledge and skills essential for enabling a lab's ability to meet its business objectives, TX empowers the R&D team to meet those objectives.

Focused Curricula. TX has designed and implemented focused curricula for several lab teams, resulting in the "just-in-time" education critical to maintaining a technically-current engineering work force, with the following results.

- The labs at HP's Cupertino site have ensured that their engineers and managers are up-to-date in the technologies directly affecting their product development work.
- The engineers new to the technologies used in the various labs have demonstrated that their learning curve for essential HP knowledge and skills is much shorter than the traditional mentor/osmosis approach to engineer training.

Graduate Engineer Education. In addition TX has integrated the graduate engineer education courses and degree programs available through Stanford University, the University of California at Berkeley, the California State University at Chico, and the National Technological University. This added learning opportunity helps to ensure that the Cupertino site engineers are kept technically current. During the past year, more than 14% of the engineers at the Cupertino Site have participated in those university courses.

6. Results

Implementation of the comprehensive and integrated TX model has resulted in significant improvements for several R&D labs as demonstrated in the following examples.

- One team reduced the completion time of a product porting process, from weeks, to less than 1 week.
- Another team demonstrated that by implementing effective software engineering methods (structured analysis, structured design, and inspections) early in their project, they significantly reduced defects in the final product. The resulting improvement in product quality will mean lower maintenance costs for that lab.
- A third team reduced their build time from three days to less than 30 minutes by eliminating the complexity in their process and by implementing a configuration management tool.

7. Conclusion

Significant improvements in HP's software products have resulted from TX's comprehensive and integrated approach to transferring software engineering technologies. Throughout the past five years, TX has demonstrated that *classes alone will not create improvements in software that Hewlett-Packard designs, develops, and delivers to its customers.*

On the contrary, R&D managers must constantly balance several factors as they bring products to market. They must be aware of all the following:

- Customer needs and requirements.
- New technologies and the technical capabilities of their own resources.

- Market windows and other factors that affect product delivery.
- Effective software development environments, processes, methods, and tools.
- Factors that influence the integration of R&D activities with the activities of marketing sales, and support teams.

They must also constantly seek ways to improve their teams' development processes so that their products remain competitive.

TX, as a function, engages in the continuous improvement of our own processes; therefore, we continue to articulate, refine, and integrate effective software engineering principles into our own process as well as in our consulting with HP's software development labs.

By providing consulting and education – involving software engineering process, methods, and tools – to R&D teams throughout HP's Cupertino site entities, the TX function has contributed to the company's ability to improve R&D effectiveness, time-to-market, and product quality.

Acknowledgements

As a reflection of the comprehensive and integrated nature of our work in TX, the content and production of this paper represents the efforts of all TX members.

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