Sustainable Technology Transfer

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ABSTRACT
In this position paper we address the issue of transferring a technology from research into an industrial organization by presenting a refined process for technology transfer. Based on over two decades of industrial experience, we identified the need for a dedicated technology engineering phase for that process. Although little attention has been paid to this technology engineering phase in the academic world, we believe it to be essential for sustainable technology transfer.

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General Terms
Management, Economics, Experimentation, Human Factors, Standardization.

Keywords

1. INTRODUCTION
Technology transfer from research into an industrial organization is a process that takes a “proof of concept” version of a technology from research as input and yields a “production proof” version of that technology embedded into that industrial organization as output. The technology is considered embedded when it is used for a considerable period of time in a number of projects. The technology is considered sustainable when its application no longer depends on the people who originally introduced the technology, such as champions.

In this paper, we focus on the transfer of software engineering methods and tools; see e.g., [2]. According to [7] a method consists of an underlying model, a language, defined steps and ordering of steps and guidance for applying the method. Examples of methods include a modeling method, such as RUP [8] and a process assessment method, like CMMi [14]. Tools will provide (automatic) support for a method, for example Rational Rose¹ or Together² for drawing Class diagrams. A technology might also be a paradigm, which is a general theory like e.g., object-oriented technology, inspections or CASE tools, like the theories used by e.g., Zelkowitz [18]. Although a paradigm is often perceived as a technology, we focus in this paper on the transfer of methods and tools.

In this paper we focus on a technology push from research to industry, which is opposed to a technology pull from research by industry. For technology push, the main forces behind the transfer reside within research, whereas for technology pull they reside in industry. The main reason for this focus is the expected interest of it for the academic world.

Our paper has the following structure. In Section 2, we briefly describe a process from technology conception to technology transfer, which includes a dedicated technology engineering phase. Section 3 elaborates on the technology engineering phase, and decomposes it into four activities. Next, in Section 4, we present a set of factors we believe have a main impact on the transfer process, although more investigation is needed. They are therefore presented in this position paper for further discussion during the Workshop on Technology Transfer in Software Engineering. Section 5 discusses responsibilities of the research and industrial parties during the engineering phase.

2. A PROCESS FOR TECHNOLOGY CONCEPTION AND TRANSFER
The technology transfer we are talking about in this paper is directed from research to large industrial organizations; hundreds of engineers building a single product (line). The research is conducted by either a university group or a research institute, but may equally well be conducted by a research department of an industrial company. Starting point is a scientific or an industrial problem. We think both kinds of problems might influence each other. The scientific problem will lead to an engineering-type of

1 Rational Rose is a registered trademark of IBM Rational Software.
2 Together is a registered trademark of Borland.
research during which the problem is diagnosed, a solution is designed that is applied and evaluated. The result is a technology that is a solution for the defined (scientific) problem. During research the technologies are created. Research can therefore be denoted as technology conception, see figure 1.

During an empirical study [2, 3, 17] the consequences of the technology, e.g., concerning its strengths, weaknesses as well as its cost and benefits are evaluated. Such empirical studies, within industry often addressed as pilots, should result in proven or evidence-based technology [6]. Pfleeger and Menezes [10] show that there are different types of evidence appealing to different audiences. The result will often be denoted as “proof-of-concept”: a proof that the preliminary method or tool has worked during a pilot project. However, industrial people will perceive the technology that results from an empirical study still as non-proven technology. The impact of the technology on their organization’s processes is still unknown. Because of the associated risks the management will not start with introducing the technology.

Technology Engineering is needed to come up with a “production proof” version of the technology. This is a matured version of the technology that will function properly in the company’s processes, and is typically customized. The “production proof” version of the technology is a prerequisite for embedding the technology. Technology Engineering is thus about the transfer from “proof-of-concept” in a “production proof” technology.

In the Technology Engineering phase a technology leaves behind the phase in which it was developed and researched. The Technology Engineering phase is actually the start of Technology Transfer stage.

In case company is attracted by a technology which has been applied by an external party, an evaluation of this technology has to be considered. Hardly any company manager will roll-out such “external” technology – even when it has been successfully applied elsewhere - immediately in his/her own company. Of course, the “showcase”-effect of such technology is important to convince people, but additional proof will be required and typically some customization as well. Because customization is expected to take considerable less effort than either evaluating a technology or developing a “production proof” version of a technology, we classify these activities for external customization is expected to take considerable less effort than required and typically some customization as well. Because of the associated risks the management will not start with introducing the technology.

We have now defined four phases of technology transfer, which are visualized in figure 1.

The four phases are qualified according to the stages Technology Conception and Technology Transfer. The distinction between the two stages requires a good interaction between Technology Conception and Technology Engineering. Research alone is not enough. Engineering is also required to industrialize the technology. Technology Engineering can be perceived as product development in a company, i.e. a department or organization between research and production.

The process we propose is inspired by our experiences at large Dutch industrial organizations that cope with software engineering technologies. The main difference with the process defined by Pfleeger [9] is that we add a dedicated engineering phase which is of paramount importance for technology push. To our knowledge, little attention has been paid to the Engineering phase so far. We therefore focus on this phase in the next two sections.

### 3. TECHNOLOGY ENGINEERING PHASE

Technology Transfer from research to industry is typically motivated by high expectations concerning lead-time reduction, efficiency improvements within the development process (i.e. cost reduction), and product quality improvements. Technology Transfer typically results in a proprietary technology that may provide the receiving industry with a competitive advantage. Unfortunately, the technology is typically not a core business of the receiving organization, and maintenance obligations might easily turn from an initial blessing into a curse. During the Technology Engineering phase the industrial organization defines how the technology can be applied in its processes.

The first activity is to define the business case for the technology. The business case addresses the company’s needs that the technology has to resolve. It includes the expected business benefits, the expected costs as well as the criteria to reject the technology; see also the factor Return on Investment in Section 4. Furthermore, risks that will negatively impact the technology introduction are identified.
Next activity will be a **stakeholder analysis**. This is the identification of the people who will benefit and of those that have to be convinced about the benefits and applicability of the technology. The stakeholder analysis helps to define who has to be consulted during the embedding of the technology.

A third activity will be to think about how to implement the technology with tooling. The prototypes that were developed during the research have to be scaled-up to the company’s needs. Mature tooling is very important. Most organizations that adopt a technology will not likely spend much effort to customization; because it is not their core business. The **Prepare tooling** activity concerns the development as well as the maintenance of the tools. In-house development of the tooling will often be the most likely step. However, we advocate to scout for standardized and existing (commercial or open source) tool(parts). In case of in-house development, it is attractive to hire the researchers that developed tool prototypes for the technology or transfer the people themselves. Maintenance of tools is especially about matching the ownership of the tooling to those stakeholders that have skills and competences for maintaining the tool. When an external tool vendor will be the best option, it is important to involve this party in the technology transfer as early as possible.

A fourth activity during the Technology Engineering phase is to define the **countermeasures** to deal with the identified risks; which are defined in the business case. For example, a possible risk for the tooling of a technology is the dependency on a particular unstable tool vendor. A countermeasure is to define an Escrow procedure which enables the industrial company to get the source code if the tool vendor went bankrupt. Table 1 presents the activities during the Engineering and Embedding phases of Technology Transfer.

**Table 1 Activities during the phases Technology Engineering and Technology Embedding**

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<th>Technology Engineering</th>
<th>Technology Embedding</th>
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<td>Define business case</td>
<td>Organize trainings</td>
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<td>Stakeholder analysis</td>
<td>Introduce technology in process</td>
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<td>Prepare tooling</td>
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<td>Define countermeasures for identified risks</td>
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**4. FACTORS**

The way in which a specific technology will be transferred to a specific company according to the process described before is determined by several factors. We think the following factors are most important; although this set is not complete:

A. **Communication**
B. **Champions**
C. **Return-on-Investment (RoI)**

A. **Communication** – this factor is about how the technology is communicated from research to the industrial organization. Industrial people are used to communicate about technologies by listening to a presentation at a conference or at company symposium. During this presentation the researcher will tell what the technology is, how it was applied and what problems were encountered during its application. Presenting the research results in a case study format [3, 17] will be an effective way to communicate. In such a way, the technology’s feasibility, cost and benefit can be shown by analogy. Researchers usually communicate to the outside world by writing a (journal) paper or report. These experiences can also be reported online in software engineering portals like www.cebase.org and www.software-kompetenz.de [12]. Researchers and industrial practitioners should be aware of their own habits in communication to avoid miscommunication.

Furthermore, also the organizational hierarchy, or the number of channels along which the technology is communicated, will impact the introduction and sustainability of a technology. The “longer” this communication is –the more management levels have to be consulted– the likelier it is that a technology is misunderstood and its effects are misinterpreted. In this context the general finding applies that companies with a low “hierarchy” (less management levels) are more innovative in average than those with a higher hierarchy [11, 16].

B. **Champions** – Champions initialize ideas and will also motivate their colleagues to work with a particular technology. The role of champions in industrial organizations is generally recognized as an important factor for change management [1, 4]. We think that a champion is really able to aspire [15]: the capacity of individuals or teams to orient toward what they truly care about. It is obvious that champions are needed during Technology Embedding. The champion conducts e.g., the change management and will also manage expectations about the technology to its colleagues [1]. But, the champion is also needed during the Technology Engineering phase. In this phase, he or she will be the manager or project leader that sponsors with advice and effort. The champion might be as well the employee that believes in the commercial application of the technology and takes time to listen to the researchers that are not understood by other industrial colleagues. The champion tries to find the right argumentation and wording for the researchers to get in touch with his/her colleagues.

C. **Return-on-Investment (RoI)** – this factor concerns the expected pay-back period of the technology. When this payback period is within the time horizon of the responsible manager(s) it is possible to start technology introduction. To speak with Sametinger [13]: a technology should only be embedded in an organization if it is expected to pay off.

The RoI can be calculated by defining Cost and Benefits. Cost will be determined by the effort of technology introduction, licenses for tools and probably the extra effort that is needed to apply the technology when it is embedded. From IT infrastructure investment analysis we know that it is easier to specify the cost of investments and much harder to specify its benefits [5]. This difficulty of determining the benefits is also true when determining the RoI of a technology. Benefits concern the expectations about the technology. It is important to specify –and possibly quantify- the benefits as much as possible. Issues to think of are lead-time reduction (a shorter time-to-market), more changeable code (improved maintainability) or less failures during system operation (improved reliability).

**5. RESPONSIBILITIES**

In this paper we looked at Technology Transfer from a technology push perspective, i.e. from research to industry. The
process as depicted in Figure 1 equally well applies for a technology pull from research by industry, however. In a push as well as in a technology pull situation the industrial company is responsible for Technology Engineering. For the pull situation this is obvious because the technology is wanted by the receiving company. The company will therefore be eager to pay for the Technology Engineering. This should also be true for a technology push. However, in a technology push the research party might be so keen to transfer its technology to industry that it will take over the responsibility for Technology Transfer. This will be illustrated by means of two examples. We witnessed a large company where the research department was very convinced about the benefits of their technology, and therefore took the responsibility for the Engineering for specific business units. To this end, the research department founded a dedicated group, whose prime objective became to develop a production proof version of the technology. This group was destined to become a self-financing activity, delivering the tooling to and maintaining it for the company. The group was also allowed to sell its technology to other external parties. Another example is a university research group that developed its own toolset. Originally, prototypes were developed to evaluate research ideas. The prototypes were quite successfully applied by a couple of companies. However, this resulted in change requests and problem reports too, requiring a lot of maintenance work. In the end the research group spent 50% of its time to maintainance instead of research. These examples show that the willingness to provide technology determines who will be mainly responsible for the Technology Engineering.

6. CONCLUDING REMARKS
This position paper focuses on technology transfer from research to industry (technology push). A process as well as a set of factors is elaborated to understand how technology transfer can sustain in a company.

The first two phases of this process – Engineering Research, Empirical Studies – concern the Technological Conception stage. Researchers are responsible for this stage. The two phases that actually belong to the Technology Transfer stage are: Technology Engineering and Technology Embedding. Our main conclusion is that the Technology Engineering phase is essential for sustainable technology transfer. However, little attention has been paid to it so far. Section 3 elaborates on the Technology Engineering phase. Section 4 presents factors that will have an impact on the Engineering. In Section 5 we argue that the company is in charge when it comes to Technology Transfer. However, the balance of interests between the providing party (research) and the party that demands a technology determines who actually will take the responsibility for the Engineering.

We challenge the members of the Workshop on Technology Transfer in Software Engineering to discuss with us to elaborate on the process and factors, and perhaps to come up with counterexamples.

We intend to come up with empirical evidence to support and illustrate the proposed process and factors. For the time being we position the process as a means for (emiprical) researchers who want to transfer their results into an industrial setting.

7. REFERENCES