Bridging the Gap: SE Technology Transfer into Practice – Study Design and Preliminary Results –

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ABSTRACT

Background: Particularly during and after research projects, technology transfer into practice plays an important role for academia to get technologies into use and for industry to improve their development. *Objective:* Our goal was to gain more and current knowledge about how technology transfer from software engineering (SE) research into industrial practice is accomplished best and how to measure the effectiveness of this transfer. *Method:* We conducted a study in the context of two German research projects, covering many different organizations from industry and academia. *Results:* This paper presents the design of the study and the survey performed. After introducing the concept of technology transfer we used and adapted, we present preliminary results. *Conclusions:* We observed that traditional means such as meetings or workshops are still the most widely used mediums for technology transfer in SE. We also discovered that, even though the duration of transfer depends on the object being transferred, the average duration is three years, which is far less than previously published (~18 years).

Categories and Subject Descriptors

[**General and reference**]: cross-cutting tools and techniques: *empirical studies, evaluation.*

General Terms

Management, Measurement, Human Factors.

Keywords

Empirical software engineering, empirical evaluations, survey, technology transfer, transfer into practice, research, industry.

1. INTRODUCTION

Technology Transfer (TT) is formally defined as "the process sharing knowledge, machines, equipment, methods, techniques, processes, and facilities with the aim of facilitating accessibility of scientific and technological developments from primary discoverers or transferors to potential users or transferees/recipients, who will exploit the technology into new products, processes, applications, and business models"[1] [11].

Interests (and motivations) for TT are various [3]: academia is interested in getting its new technologies into use and in understanding their applicability, whereas industry needs to know about the newest technologies from research that can help them to improve their development or increase their competitiveness on the market. More generally speaking, TT is a key aspect for the technological innovation of any country. Despite the strategic importance of such factors for all organizations and people involved, in Software Engineering there is less reporting about explicit work regarding how TT is done at the moment, which kind of transfer is being performed, and many other aspects [7].

We found only one older literature reference stating that TT takes about 18 years for enhancement and exploration [8]. Also, not much is known about the impact of many research projects (often funded by government or other public institutions) on actual industry practice. In particular, it is unknown which research project results remain at the prototype stage and which are really implemented and used after the project by industrial companies (e.g., as reported in [14]). Usually the only measures of impact reported are citations, licensing, and patents count [13]. The main open questions, even for the institutions funding such projects, are thus: (1) *how* to best transfer results from research into industrial practice; (2) how to *measure* the effectiveness of such transfers.

We decided to investigate these important aspects in the field of SE by focusing on the first aspect. Our initial step was to conduct a survey on TT in the context of two large, heterogeneous projects in Germany (ARAMiS[2] and SPES-XT[3]), with industry and research partners developing a great number of methods, procedures, and tools with the purpose of transferring them to industry. In this paper, we describe the design of this first study and show preliminary results for the following questions: How long does TT usually take? Which mediums are used most often?

The remainder of the paper is structured as follows: In Section 2, we specify TT and in Section 3 we show how our specification relates to the most relevant models presented in the literature. We describe our study design in Section 4, including the objective, the questionnaire design, its validation, and the preliminary results. Finally, following Section 5 on the threats to validity, we conclude the paper in Section 6 and present our future work plan.

2. TECHNOLOGY TRANSFER

According to the above definition of TT, we specified – for the purpose of our survey – the TT process (see Fig. 1) as the transaction of a transfer object (knowledge, machines, etc. [11]) between the transferor (organization seeking to transfer the object)

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[1] We added the word "techniques", which complete the set of possible transfers in SE.

[2] http://www.projekt-aramis.de/ (Dec. 2011 - Nov. 2014)

[3] http://spes2020.informatik.tu-muenchen.de/spes_xt-home.html (May 2012 - April 2015)

and the transferee (organization receiving the transfer object) over a medium (e.g., guidelines). This specification was included in the survey with the intention to establish a common understanding of TT for all participants. For this reason, we decided to simplify some things. In particular, we assumed that:

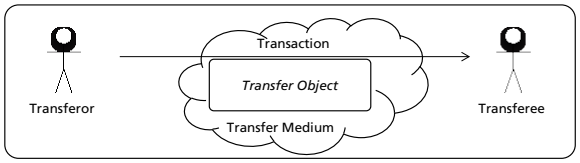

Figure 1. Specification of the Technology Transfer process

(1) TT is a unidirectional activity from the transferor to the transferee and (2) is not mediated by further actors between the transferor and the transferee. TT is indeed a very complex phenomenon and these assumptions are not always valid in common academia-industry collaborations. For instance, in an evolutionary mediated schema [1], transfer is done through continuous feedback cycles between transferors, mediators (brokers), and transferees. Although adherence to strong assumptions might limit the scope of validity, the context of this survey allowed us to safely approximate the transfer in ARAMIS and SPES-XT with such a concept.

3. RELATED WORK

We defined our own TT concept (Section 2) with the intention of reducing complexity in order to avoid discouraging participants. Still, by construction it adheres to a well-known definition of TT [11] and was carefully aligned with models found in the literature. Given the importance of the specification for the design and operation of the survey, we report how our specification is related to the most relevant TT models in the literature.

We first take a look at cross-disciplinary models. Reisman [9] developed a taxonomy that takes into account four elements: *actors*, *transaction types*, *motivations* and *disciplines/professions*. From both the terminology and the conceptual point of view, our specification adheres completely to the type of actors defined by Reisman. For the motivations we included a specific question for tracking them (Section 4.1). Finally we did not specify the discipline since we are focused only on SE, and we do not look at transaction types, but directly at related mediums.

Bozeman [3] built a comprehensive model of TT to support the study of TT impact and effectiveness, which is very interesting for the follow-up of this survey. Bozeman's model has two actors, with the following mapping: *transfer agent (transferor)* and *transfer recipient (transferee)*. Our characterization of the mediums is more fine-grained and comprehensive, as the mediums are one of our main goals (Section 4). The transfer object is presented in more detail in our specification than in [3]. The final element is the demand environment, which corresponds to the motivation of [9] and is traced in a question (Section 4.1).

Looking specifically at SE, the model presented by Rombach and Achatz [10] is organized in steps and is related to a specific collaboration with an industrial partner. We took into account its static attributes, i.e., the characterization of the *invention user* (transferee) and the *invention provider* (transferor), the transfer object, and transfer medium.

Gorschek et al. [5] also propose a TT model for SE and sketched a 7-step process. Although this process is certainly a reference for our execution of TT in the follow-up study, it does not provide the static elements we need to characterize TT and reach our goals.

Even though many different TT models exist, almost none offers data about its application. Our intention and main contribution is to characterize our simplified TT concepts with data.

4. STUDY DESIGN

This section focuses on the design of the study, especially its objective, the final questionnaire design, and its validation. The last part contains preliminary results with a discussion.

Study Object. TT in SE is the object of our study, due to its importance for research as well as industry.

Study Goals. First, we want to gain deeper insights into how TT is performed at the moment (SG1). Second, we are interested in which transfer mediums (SG2) are used in the transaction: A former study [4] reported that very few works address this specific part of TT. Last, future improvements (SG3) in this area are of huge importance for us as researchers to help industry. Formally, the different goals of this empirical study were to:

> *Characterize the TT of SE objects with respect to the current state of the practice (SG1), the transfer mediums used (SG2), and improvements or future transfer trends (SG3) from the industry and researcher perspective within the software engineering domain.*

How these three study goals are implemented and related to the specific questions in the questionnaire will be explained in the next section, especially in the "Transfer into practice" part.

4.1 Questionnaire Design

Due to space reasons we describe only the structure of the questionnaire and the rational of the specific aspects investigated. The full questionnaire and implementation details – such as style of the questions (open/closed, answer options) – are online[4].

The structure starts with an explanation of the purpose and context of the study. Afterwards, the demographical aspects are collected. Then the TT definition (see Section 1) and the simplified concept are given (see Section 2) to ensure that all participants have the same level of knowledge. The TT-related questions are separated into three parts in accordance with our study goals: (SG1) the current state of TT, (SG2) the assessment of different transfer mediums, and (SG3) improvements. How these parts are further subdivided and implemented in questions will be explained in the following.

Demographical aspects. For this part, we mainly tailored the validated demographic questions of [4]. Only the *organization type* was specified in more detail, similar to [10], in order to distinguish between research and applied research (e.g., Fraunhofer IESE) as well as between organizations' research units and their business units (BU). In addition, the *degree of education* as well as *previous work in industry or academia* (academia includes universities and research institutes) were important as variation factors for future analysis of the data.

Transfer into practice. We first checked who is currently performing TT and in which role (transferor (TR), transferee (TE), or both (TR/TE)). Thus, only specific groups needed to answer different parts:

[4] The full questionnaire is available at: http://www4.in.tum.de/~vetro/esem2014/esem2014-TT.zip

- SG1 - Current state: TR/TE, currently performing TT
- SG2 - Medium assessment: TR/TE, currently performing TT
- SG3 - Improvements: TE

SG1 - Current state: We are interested in assessing the current state of five different aspects: (1) the motivations behind TT, following the classification of [9]: *social*, *economic*, *operational*, *strategic*, *global,* or *personal factors* (we provided the possibility to indicate an additional one); (2) the type of transfer objects from the list provided by the adapted definition of [11]; (3) the transfer process description, which was an open question; (4) time: average duration and frequency of a TT transaction and the related perception/opinion of the actors involved; (5) origin/trigger of ideas for TT (TE, possible options: research; competitors; other companies; consulting company; own company).

SG2 - Medium assessment: We created a broad classification of mediums and asked the participants to indicate on a 5-point scale of frequency how often they were using them. In a subsequent question, we also asked which transfer mediums they believed to be best for which specific transfer objects.

The mediums were classified following a literature analysis, using comprehensive taxonomies previously published (e.g., [3] [9]) and brainstorming sessions in our respective affiliations. We collected 98 types of mediums from eight publications and two brainstorming sessions, reducing them to 64 after a duplication analysis. Due to this large number and the need for commonly understood terms, we ended up with a two-layer classification schema (Table 1) using the TT models collected by Pfleeger [7] (from [2]) and expanding them where no match was possible. The rule model [12] (which is transversal and simply means that TT is enforced), the organizational model (e.g., company acquisitions), and the "informal cooperation" from the cooperative model were excluded because of our scope. It was important for us to include guidelines, as this is the medium being used and improved in the projects [6].

Table 1. Medium classification

Models (1st layer)	**2nd layer**
People-mover model [2]	Personal exchange
Communication model [2]	Publications
	Internet resources
	Conferences, workshops, etc.
	Guidelines
Vendor model [2]	Consultancy
On-the-shelf model [2]	Software, systems, and tool
	Standards
Cooperative model	Co-working
	Licensing
	Research cooperation
Educational model	Educational programs

SG3 - Improvements: In this questionnaire section, we collected indicators for improving TT in the continuation of the projects and in general. The main focus was on the goals for TT. We asked this in an open question for two reasons: (1) to check whether goals are the same as motivations; (2) to understand how to do measurements in follow-up projects regarding these goals.

4.2 Design Validation

Peer reviews. Two researchers with experience in transfer projects and empirical investigations reviewed the questionnaire draft in terms of understandability, completeness, and project relevance. Afterwards, we discussed anything ambiguous, missing, or unnecessary with them. The implemented online questionnaire was assessed for consistency to verify the correct configuration of filters and hiding conditions.

Pilot tests. A pilot test was then performed with several researchers. Here, we identified the risk that the long definition of TT might encourage some participants to abort the survey.

4.3 Preliminary Results and Discussion

Here we provide some preliminary results on time to transfer (SG1) and mediums used (SG2), including improvements (SG3). We use the median (*Mdn*) and partly the mode as a measure of central tendency, and interquartile range (*IQ*) for dispersion. The demographical aspects are given to get an idea of the respondents. They are not used for further variation analysis here.

Demographical aspects. From the 41 organizations (26 industry, 15 academia) participating in at least one of the research projects, we had 45 participants for the survey, but the dropout rate was 51%, mainly in the introduction and current state sections. For the preliminary results, we decided to use only the 22 participants who completed the survey. Most of the respondents work in large organizations. Almost 70% (*n=15*) reported to be part of an organization with more than 500 employees; 20% (*n=4*) belong to organizations with 50 to 250 employees. About 60% of the organizations (*n=14*) are from industry and half of them belong to their research units. The remaining 40% (*n=8*) are academic. Participants come from different domains: automotive (*n=6*), automation (*n=5*), railway, avionics, and tools (each *n=3*). The distribution of TT role is imbalanced: 13 TR, 2 TE, and 7 both.

Time for transfer. 20 of all responding participants answered the question about how long TT takes on average at the moment. Of the 19 participants with real answers (*I don't know: n=1*), 58% think that TT takes years (*n=11*): with a range from one to ten years. The answer of most participants (*Mode=1*) was one year, although the median of years was three (*IQ=2.5*) similar to the average, which is nearly three (2.93). The other participants answering with numbers stated months (*n=3*) or weeks (*n=2*). Since five participants think that it depends on the object being transferred, this could be an important variation factor.

Compared to Redwine and Riddle [8], our results show that the time for TT has decreased a lot in recent years, from around 18 years to an average of three years (one outlier with 10 years). Nonetheless, the results of the question whether the time should be shorter, longer or is fine showed that there is further improvement potential for the duration of TT. Of the 14 participants (*I don't know: n=6*), 57% think the duration is fine (*n=8*), 38% think it should be shorter (*n=5*). This also confirms our overall improvement idea of shortening TT duration using all possible TT-related aspects, e.g., the most appropriate medium.

Mediums. Figure 2 represents the distributions of all answers for the currently used mediums, with participants indicating the frequency of TT on a 5-point scale. The most frequently used transfers are workshop and meetings (*Mode=4, Mdn=4, IQ=0*), and personnel exchanges (*Mode=4, Mdn=4, IQ=1)*. Less common are educational programs (*Mode=2, Mdn=2, IQ=1*) and licenses/standards (*Mode=1*, *Mdn=2, IQ=1.25*). It is interesting

that patents and licenses, which are commonly used to measure the effectiveness of transfer results [13] (see Section 1), are rarely used in these projects, confirming that other measurements will be needed in the follow-up of our work. The use of guidelines is another interesting result: although they are formally a transfer medium built ad-hoc for projects, their usage is strictly dependent on the respondent (*Mode=3, Mdn=3, IQ=1.5*): this may also be an indicator for further improvement. Finally, if we split the mediums into two sets, i.e., artifact-based mediums (e.g., tools) and human-intensive mediums (e.g., personnel exchanges and meetings), we observe that the latter are used slightly more often.

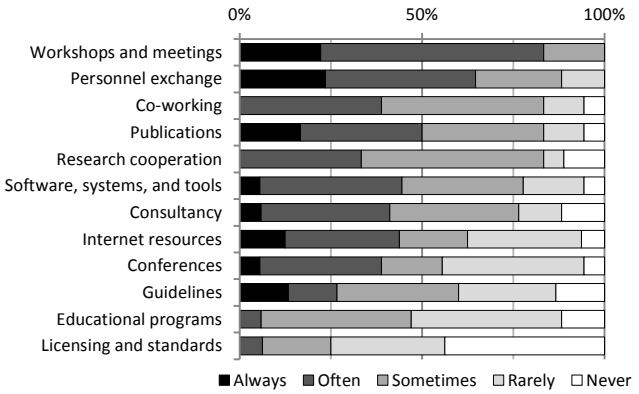

Figure 2. Current use of selected transfer mediums

5. THREATS TO VALIDITY

Internal threats. The simplified model used for representing TT is coarse-grained and do not fully capture the interaction between transferors and transferees and the dynamics of the whole TT process (as the imbalanced distribution of TT roles suggests). We mitigated this threat with an explicit (optional) open question for describing the process. But the choice of this simplification permitted to reduce the risk of different mental models among participants, reducing the corresponding threats.

A conclusion threat regards the interpretation of the transfer time results: we are well conscious that it depends on the transfer object, however this result is useful as a reference for improving the transfer time in the practice of the ongoing projects by selecting the most suitable mediums for specific objects.

External threats. The scope of validity of this survey is limited to the two German national projects ARAMIS and SPES-XT, and more specifically to the area of TT of SE for embedded systems.

6. CONCLUSIONS AND FUTURE WORK

This paper provides a simple TT concept used for the purpose of collecting up-to-date information about TT through a survey performed in two large German projects. We provided an overview of the study design and some preliminary results about TT time and mediums used: we observed that, although the duration of transfer depends on the object transferred, most of our participants reported durations of years. The average value (3) is much lower than previously reported values in literature (18), however it is still not satisfying for many respondents. We also observed disproportions in the most used transfer mediums, with prevalence of traditional and human intensive ways.

Our plan for future work consists of several (non-exclusive) options. The main follow-up will be to analyze all study results and compare the relationships (1), and to extend the survey to other domains (2), countries (3), and companies (4). We also aim at improving TT in the projects, mainly focus on guideline creation [6]. This will be done qualitatively, with semi-structured interviews and war stories (5), and quantitatively, by measuring the effectiveness with respect to specific goals (6). We will also work on complex specifications and the process definition (7).

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