Toward Technology Transfer Evaluation Criteria

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Abstract

Technology transfer is often focused on how to get novel technology transferred into an industrial using group or company. We focus in this paper on the target of the process and present guidelines which can help assess the likelihood of a successful transfer.

1. Introduction

Someone once told us, as young researchers back in the beginning of computer graphics, that transforming a thing that works into something that WORKS is hard and takes more effort than the initial development. We didn't understand it then. Over years of trying to get new technology successfully adopted in industry (even when we were directly employed by industry), we gradually came to understand that the transfer process is neither easy nor straightforward.

Researchers are often more concerned with novelty than applicability. They are measured by publications, and reviewers tend to emphasize novelty much more than applicability. Of course, a project can do both. Doing both is much harder than just novelty. Researchers need to make sure their new method or technology actually solves a problem that is important to the business community, that it reduces a pain point. As Fred Brooks [5] noted:

> *A toolmaker succeeds as, and only as, the users of his tool succeed with his aid. However shining the blade, however jeweled the hilt, however perfect the heft, a sword is tested only by cutting. That swordsmith is successful whose clients die of old age.*

Our belief is that new technology that increases client's/user's success is the ultimate target of technology transition.

In this paper, we examine issues we consider important in undertaking technology transfer, identify problems, and develop some criteria/guidelines. We hope the criteria will help in assessing – and assisting – both technology and receivers in increasing the probability that future transfers are successful.

2. Background

Moving forward with new technology is a well-discussed, mature topic. There are clearly numerous factors that control the rate of adoption. The rate itself is discussed in [11]. Moore modified the classic adoption curve to add a particularly large gap, which he referred to as a 'chasm', between the early adopters and the early-stage main majority. The chasm was meant to emphasize the significant difference between these groups. Early adopters are the visionaries whereas the early majority are pragmatists, only wanting to work with proven technology, technology that many others have already used successfully.

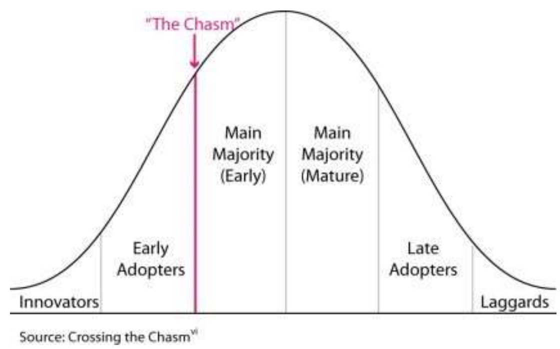

Figure 1. Technology adoption curve with chasm

The introduction of the chasm parallels the authors' experience with technology transfer. There are extensive publications on the technology transfer process itself [11].

Though Moore addresses the marketing of new technology products by high-tech companies, we believe his concept applies equally to the transfer of technology from academia to industrial firms – and more generally from any R&D group (whether small "r" large "D" or vice-versa, to any receiving/using group.

What is less clear is that the duration and depth of the chasm varies significantly. In exploring the reasons for the different time frames [6], the authors examined the time it took for large corporations to adopt, even in a limited manner, new computing technology. Adoption times varied significantly, from 10 years to not being

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adopted at all. In all cases, adoption times were surprisingly long.

The hypothesis in this paper is that having a set of clear guidelines, understandable and available to both technology developers and potential recipients, would be useful to both groups. Technology practitioners often believe that their work is beneficial and applicable to even the most stubborn customer. Conversely, and not widely understood, potential recipients on the far side of The Chasm often find reasons (both rational and irrational) to reject new technology and prevent competition with current practice.

The intent of this paper is to develop and present a clear set of guidelines to assess the likelihood of successfully transitioning technology from a supplier (developer/researcher) to an industrial firm. If the guidelines are applied effectively, such projects should be more likely to achieve success (or to fail more quickly), decrease the overall time needed for adoption, and help bridge The Chasm.

The paper does not attempt to define a rigorous process to apply the criteria or run a technology transition project.

3. Proposed Criteria

In our research, we saw dozens of papers that talk about running technology transition projects, which is certainly necessary. Our guidelines are independent of the many different transition project management possibilities.

There are clearly hundreds of dimensions that can accelerate or deter technology adoption. In spite of the breadth and depth exploration of the technology transfer process, there has been little exploration of the factors that *influence* technology transition. [12] did develop excellent criteria for judging the success of a project. Our intent is different because we want to increase the probability of successful transition and therefore complements Tan's work.

The authors identified four high-level areas with factors that influence the adoption of new technology and developed guidelines to help assess the adoption opportunity:

- Demonstrated applicability to a company's business problems
- Willingness of the business community to adopt the concept
- Willingness of the technical community to *support* the concept
- Adaptability to corporate infrastructure

The general relationships among these factors are illustrated in fig. 2, which shows the model we have adapted to describe the technology transfer-adoption - transition process.

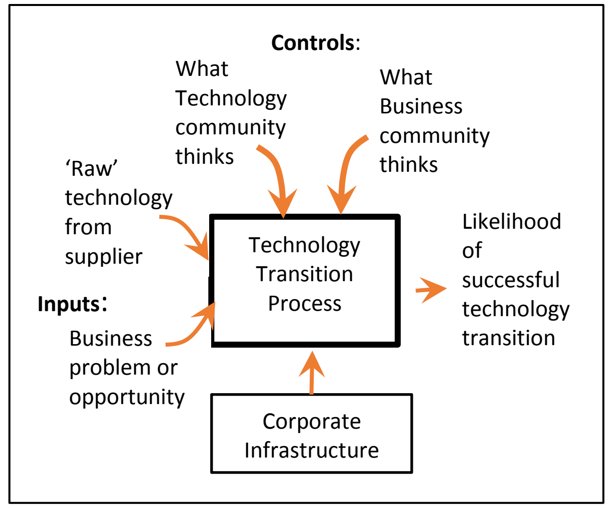

Figure 2: Model of technology transition process.

Even though our primary experience is with computing technology, we assert that our guidelines apply to transitioning and deploying any new technology. Inputs (arrows from the left) to the model are the technology to be transferred/transitioned and the business problem to be solved. There are two controls (arrows from the top): what the technology community or supplier 'thinks' and what the business community or receptor thinks. The environmental infrastructure (called mechanisms and represented by the arrow at the bottom) defines the context into which the new technology must fit or which must be changed to accommodate the new technology. By applying the criteria discussed below, we produce the likelihood (the arrow on the right) that the technology will be adopted. The process is iterative. Changing the inputs, controls, and mechanism can increase or decrease the odd of success.

Primary inputs:

- The technology itself. We don't restrict the supplier of the technology to an academic research group: it could equally well be another company or another division/department within the receiving company
- Applicability to business problems. Applicability is of course crucial - suggesting that a specific technology is applicable to a company without a demonstrated fit makes success virtually impossible. Note that the need for any imported technology can change over time. For example, Boeing hired the U.S.'s leading concrete experts in the 1960's to insure success in building Minuteman missiles in the cold climate of the Dakotas. Once the project was successfully completed, the experts

gradually left and were not replaced. Similarly, GM developed significant computer graphics expertise in the ‘60s and ‘70s in order to develop its CAD system, but as third-party firms developed suitable products and expertise, GM’s need was correspondingly reduced and they moved from an in-house system to a vendor-supplied one.

Controls govern the internal rapidity with which new technology is adopted. The controls can result in a range of rates from rapid deployment to total stoppage and include:

- Willingness of the business community. The business community contains the people, data, and materials that define and solve specific product-related problems. This community produces new knowledge, products, ideas, etc. that others consume. For example, intelligence analysts are given problems and data from which they make recommendations. Political, military, and business people make decisions based on analyst recommendations and other information. Ultimately, the business community will directly use new technology.
- Willingness of the technical community. The business community often asks the technical community to independently examine the robustness and suitability of new technology. The technical community may be inside or outside a company.

The mechanisms of the corporate infrastructure must be understood to assess the amount of change that may be needed to implement new technology in production. In this case, the mechanism is:

- The existing corporate infrastructure-environment. Any company, be it a century old or a start-up, has operational constraints. Infrastructure mechanisms range from supply chain to drayage to computing resources to job definitions to available electrical power to business community expertise. New technology must be able to fit into the environment or justify modification/expansion. For example, all-electric cars work wonderfully as long as there are reliable charging stations. Adding stations to make recharging as convenient and readily available as fossil fuels is happening gradually.

The model output is the likelihood that the technology will be adopted. The rest of this section describes the criteria the authors, both of whom worked as transfer technology insiders in large companies, learned that must be considered to improve the chances of a successful transition of a specific technology.

The authors recommend that readers assess all aspects listed below early and often to increase the odds of success. Implementing any technology successfully is a time-consuming process, often a multi-year or even multi-decade task. Assessing early and often should reduce the time taken by ‘The Chasm’ in Moore’s technology adoption curve and make new technology more broadly available in a shorter period of time.

By technology community, we refer to the group supplying the technology to be transferred. This could be an academic research group or an R&D group within the (receiving) business community, a start-up company, or a new supplier.

By business community, we refer to the organization to which the technology is proposed to be transferred.

Thus the two sides of the transfer process, on opposites of the chasm, can be in different organizations or in the same organization. The authors have experienced both types of transfer efforts. For example, we have successfully transferred technology from an academic research group to a large corporate entity and have been part of successful efforts to transfer technology from a corporate research division into manufacturing divisions.

3.1 Applicability to Business Problems

Here we identify issues and topics that must be addressed within the receptor or business organization with respect to the problem being solved. The basic theme is that the probability of success increases when the business community can be convinced that the new technology can address real problems. Involving the business community directly helps get buy-in.

Identify business people who understand the current situation and can articulate problems.

- When there are multiple business people who understand the situation, pay attention to the internal stature of each person. Are you dealing with a user, or with a ‘chooser’, i.e. the individual who will ultimately decide to accept or reject new technology? Are they high enough in the organization to control the resources needed for adoption?
- Examine cause and motivation for the perceived problem(s).
- Identify specific cases that are problematic; generalizations are difficult to sell internally.

Find test cases and data sets for experimentation

- Willingness to explore specific cases that cause problems

- Accept that modifications to new technology may be needed in case exploration has poor results.
- Be prepared to deal with difficulties in obtaining access to data – many 'owners' are very protective.

Review results with business people

- Get first hand reaction to test results
- discuss with both users and choosers who may have quite different viewpoints.

Document and communicate what went well and what didn't go well

- Show results outside business circle
- Get peer review to technical approach
- If reasonably successful, present to other business communities

Take results to multiple levels of management

- Identify additional audiences
- Build case for funding transition

Know when to quit in the face of continued resistance

- Be realistic should there be no perceivable movement

3.2 Business Community Adoption

Any business community has a set of entrenched tools and techniques. New technology is often a threat to adoption. Adoption odds increase when the technology-providing organization understands the existing environment. In short, these criteria help understand the competition and position the new technology.

Understand existing technology. If you are proposing for e.g. a new software tool, make sure you understand the one in current use.

- Understand the pricing of the current tool set
- Have an idea of the number of people using the tools; convincing a few users to change is easy; persuading several hundred is an entirely different – and much more expensive – task.
- Determine advantages new technology may have

Look for places where existing tools have problems that new technology (must) solve

- Know the limitations of existing tools as applied to specific business problems
- Enlist people in the user community who may have problems to participate in early tests

Do not indict existing tools directly

- Most user communities love their existing tools even if they have issues
- Understand the limitations in new technology

3.3 Technical Community Support

Most organizations have technical staff who help assess and position new technology. In many corporations, the technical staff is in a separate group, e.g., the dreaded Information Technology organization for new computing tools. Internal research groups may have competing technology and act as a roadblock. There are a variety of social and psychological issues related to the business' technical community that must be addressed in any effort to transition in new technology:

Invented here

- Management and users often believe that technology can't be worth much if someone local thought of it first.

Not invented here

- Most user communities have technology advocates who believe that any technology not invented or discovered internally is probably inappropriate or inadequate.

Threatens technical expertise

- Technical organizations will protect their approach because of staffing and funding issues

3.4 Infrastructure Conformance

An often overlooked aspect is an understanding of the actual infrastructure of the receiving organization. Essentially the better understanding one has of both the capabilities of the components of the organization and the capabilities of each, the higher the likelihood of success. Ideally, new technology is designed to fit into the infrastructure *ab initio.*

Organizational impact

- Where are the organizational experts in existing technology?
- Impact on existing tools and methods
- Salary and job descriptions
- Market demand for specific skills
- How to provision for a broader community
- Training
- For truly new technologies, how to supply skills when demand increases

Technical infrastructure impact

- Understand existing tools and their support structure (e.g., standards)
- Impact on physical resources (e.g., compute and network power)
- Gaining access to data
- Information security

4. Applying the Model: Selected Examples

Since hindsight is 20-20, we applied the model (Figure 2) to multiple projects in which one of us was directly involved. We identify the criteria that was most influential in making the project a success or failure.

4.1 GM CAD

The application that pushed the initial development of computer graphics was computer-aided design; early research took place at MIT with Sutherland's Sketchpad and at GM Research with DAC-1 in the early '60s. At GM, CAD was 'sold' to upper management as a way to reduce cost. In practice, it was used to explore more ideas in the same time, thus producing better designs, but at little actual cost savings.

The technology community - researchers at GMR – spent a considerable effort in studying what their business community really wanted [10]. As Krull noted [10], one of the first things the research group (technology supplier) did was to hold discussions with their business community – the Design and Engineering Staffs – where specific tasks were identified (see criteria in section 3.1) The question that was being asked was, "How could computational techniques significantly impact the design process?" Additionally, multiple levels of management were involved, from a high level Styling manager down to individual designers (section 3.1 item 1). Documentation was extensive, including publication – peer review (see section 3.1). The result was the DAC 1 system which was in essence a very successful 'existence proof' that was used to demonstrate capability.

To cross the gap, both a more capable system was needed and additional work was required along the lines of the items in section 3.2 with the internal business community in the form of the motor divisions. Considerable effort was spent to convince their design management of the probability of success, of the probability that this new technology would actually save money and time. It was a difficult line for the technical community to walk however, since once the managers became convinced, they wanted it all, immediately, and getting new technology into production of course is never immediate.

In this case, our fig. 2 model would suggest a high likelihood of success, given the extensive engagement with the business community and the understanding of the corporate infrastructure and indeed the project was successful, resulting in one of the earliest production CAD systems.

4.2 Boeing CAD

Boeing moved into the world of CAD in the late 1970's as it developed the 757 and 767. The initial choice of tools targeted producing engineering drawings: computer-aided drafting rather than computer-aided design tools. The FAA insisted on drawings as the build authority, and Boeing staff was accustomed to the drawing process. Both airplanes were commercial successes. The 757 ceased production in 2004 because of fuel consumption. It has yet to be replaced by either Boeing or Airbus. The 767 is still in production as a freighter and as the basis for the KC-46 tanker.

Boeing quickly realized that the underlying mathematics in drawing systems needed to handle 3D surfaces and solids. Therefore, the company started the TIGER research program in 1980 and launched a commercial product called Axxyz. The underlying math basis was non-uniform rational b-splines (NURBS) [4].

From a technologist perspective, the developers achieved significant success. From a business perspective, the project failed. Looking at the criteria in section 3, showed that:

- The developers did not accommodate import from or export to other CAD systems until the late 1980's. They believed that all work could be done in Axxyz.
- Direct user involvement was limited and occurred grudgingly. In fact, most 'users' were part of an intermediary organization and not doing design work directly.
- The user community was happy producing drawings.
- A business commitment caused Boeing to purchase CAD software from Dassault Systemes in 1988. Since Boeing wasn't using Axxyz (the commercial variant), the project died.

4.3 Boeing Massive Model Viewing

Designing aerospace products often stresses visualization software to its breaking point. Boeing developed FlyThru, a heavily used Silicon Graphics-based viewer, in the early 1990's [3]. FlyThru displayed as much geometry as could be fit into an SGI's memory, about 5% of the geometry needed to represent a complete airplane.

A PC-based viewer called IVT (Integration Visualization Tool) appeared in the early 2000's that mimicked FlyThru in both function and capacity. The primary users were for the 787, which doubled the amount of 3D geometry over the 777.

The development group had worked with the academic community to stimulate software development to produce software that could interactively display an entire 777. The field became known as Massive Model Visualization (MMV) [14].

The resulting IVT extension, called Superviewer, has been in production use since 2006. While making Superviewer a production capability, it was not used widely until 2013-2014. Looking back at the Section 3 criteria, Superviewer did well by:

- Finding commercial software (a library called vgr [2] that could be integrated directly into IVT. This made the user community happy because they did not need to learn a new interface.
- Requiring little change to IVT software infrastructure.
- Using the same data as 'regular' IVT.
- Engaging end users to evaluate as development progressed.

Broad adoption slowed because:

- The groups that have used Superviewer most extensively did not appear until ~2012. The developers assumed that design reviews would benefit most. It turns out that manufacturing and support have had significantly more benefit.
- Modification of IVT functions to work with Superviewer progressed slowly because of funding limitations.
- Pre-processed Superviewer-formatted data did not exist until the early 2010's.
- Technical staff argued for other commercial viewers that did not scale.
- Research staff developed their own special purpose viewers and did not care about MMV scale.

Based on this, the odds of success were medium. Engagement to understand the breadth of applicability occurred much later than it should have.

4.4 Microtel Pacific Research and Intelligent Graphic Interface

The technical problem was managing complex hierarchical networks such as power distribution networks or telecommunications networks [9]. The technical community however was a combination of an academic research group and an industry applied research group (MPR), with the business community being the parent company of industry research group. This effort was a technical success, and having spent considerable effort on the issues of 3.2 and 3.3, at least got to the prototype stage, but ultimately the project faded in part due to not understanding the infrastructure of the business community well enough and not getting sufficient buy-in from senior levels of management in the business community.

4.5 Continuous Zoom and Thoughtshare

Here, a successful research project on visual navigation of the web [8] was spun into an ultimately unsuccessful startup [1] because the founders didn't pay enough attention to their business community, i.e. to the marketing. They failed to identify specific business problems that their technology would solve. So while the technology was successfully transferred into the startup from a research lab, the startup failed to pay enough attention to their 'business community'. The model in fig. 2 would suggest a very low likelihood of success (see 3.1).

5. Assessment

The long-term basis for technology transfer is understanding the overall success of the technology adopters, not the developers. Looking at projects ex post facto shows applicability as a way to assess the cause of project success or failure.

A part of future work in this area would be to apply the guidelines to current 'hot' topics (e.g. augmented reality, artificial intelligence, machine learning, virtual reality, driverless cars) and track progress over time.

6. Conclusion

In this paper we've developed a model of the process of transitioning new technology from a "development group" we called the technical community, into a "using group" which we called the business community. The model is based on experiences, some even successful, in technology transfer. Our model included basic inputs - the technology and the problem being solved – along with controls – viewpoints of both communities – and the mechanism of understanding the infrastructure of the receiving community. Using this, one can get a measure of the likelihood of achieving a successful transfer. We elaborated each of these items and described specific, real examples of technology transfer and tried to relate those to the model.

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