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Tracking Evidence of Knowledge Use Through Knowledge Translation, Technology Transfer, and Commercial Transactions

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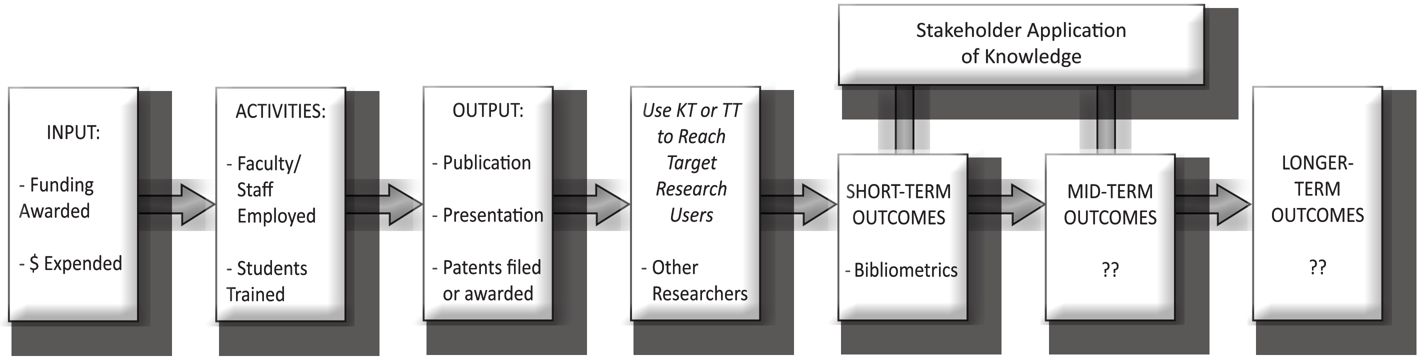
This* FOCUS Technical Brief *extends* FOCUS No. 26*, which considered the processes of knowledge translation (KT) and technology transfer (TT) in technological innovation. Here, we explain that both KT and TT contribute to accomplishing yet a third process—commercial transaction—which is the actual transformation of knowledge embodied in products and services into beneficial socioeconomic impacts. Planning, managing, and documenting the progression of knowledge use through the technological innovation pipeline culminates in an exchange of utility between the producers and consumers of knowledge through this market mechanism.

Research Value to Society

Government agencies sponsor a variety of applied research programs, either internally through government laboratories or externally through universities and affiliated organizations. Over the past decade, these agencies have come under increasing scrutiny by elected officials, as well as the general public, to demonstrate evidence showing how outputs from research result in beneficial impacts for society. In the United States, this scrutiny is grounded in prior law through the Government Performance and Results Act (GPRA) of 1993, which holds government agencies accountable for achieving intended results, including programs sponsoring extramural research or development activities (Office of Management and Budget, 1993). The European Union's (EU) Framework Programme has sponsored international research and development collaborations intended to generate technological innovations over the past 30 years. With the framework now in its 7th cycle, there are widespread calls for increased accountability regarding the outcomes and impacts of this extensive and sustained investment (Community Research and Development Information Service, 2012).

The implied promise of societal benefits has remained the primary driver of government support for innovation, resisting all attempts to clarify or correct the underlying assumption. The genesis of this assumption, its consequences and weaknesses, have been thoroughly analyzed in prior publications (Guston & Keniston, 1994; Stokes, 1997). This perspective of funding one sector now so that another sector will benefit in the future is known as "linear innovation" in science models, "supply push" in technology

Figure 1: Logic Model Chain of Events and Measures



models, and "trickle down" in economic models. This perspective persists in many government policies and programs despite evidence that the approach does not generate the intended outcomes or impacts for society (Sarewitz, 1996).

Of course, the times are changing. Government agencies are increasingly tasked with demonstrating that the findings generated as outputs from sponsored research projects in universities are in fact being put into use by various stakeholder groups, both inside and outside the realm of academe. In the parlance of logic modeling, the *research findings* are outputs that occur in the short-term at or near the completion of the funded research activity (Stone & Lane, 2012). The *stakeholder applications* are outcomes that occur in the short-term and mid-term after the research findings are shared with stakeholders. This sharing may be passive through publication or active through training, demonstration, or technical assistance. In the long-term, the outcomes are expected to generate socioeconomic benefits for society, referred to as impacts (McLaughlin & Jordan, 1999).

Funding agencies and grant recipients already apply some metrics to verify the contributions of research to society. As depicted in Figure 1, these efforts are typically limited to measuring things that can be quantified, such as the dollar amount of funding awarded or expended and the number of faculty and staff employed, graduate students trained, publications generated, presentations made, or patents filed and/or awarded.

From a broader perspective, these measures are recognized as representing the inputs, activities, and outputs of a specific project or program. However, as shown by the question marks in Figure 1, they do not represent the mid-term or longer-term outcomes generated through the application of knowledge by non-academics, nor do they measure the societal impacts that manifest from such applications. These shortcomings have negative budgetary implications, because programs that do not meet the broader expectations for demonstrating knowledge use may be diminished or eliminated.

Knowledge Translation to Increase Knowledge Use

In order for agencies and grantees to demonstrate evidence of value to society, these surrogate measures of process are giving way to actual evidence of utility to stakeholders outside of the academic system and to the targeted audiences intended to benefit from the public investment in sponsored programs and projects. Discoveries from basic research should have a pathway for reaching relevant fields of potential application. Findings from clinical research studies are supposed to become integrated into treatment protocols. Similarly, prototype devices are supposed to become integrated into technology-based products available in the marketplace.

Given the new expectations for demonstrable evidence of downstream effects from research (outcomes and impacts), an entirely new field of *knowledge translation* has emerged to make better use of completed research discoveries in health-related fields and to increase the societal relevance of ongoing research (Canadian Institutes of Health Research [CIHR], 2004). Since many specific translation strategies depend on the content of the substantive research results, systematic approaches such as the Knowledge to Action (KTA) Model, promulgated by the CIHR (Graham et al., 2006), are emerging for improving communication about research-based outputs from the scholarly investigator to various target audiences who have a reason to put these knowledge outputs into use.

It is important to recognize that publicly funded projects are not limited to scholarly research activity. Some government programs (e.g., the National Science Foundation's Engineering Research Centers [ERC] program; NIDRR's Rehabilitation Engineering Research Centers [RERC] program) sponsor technology-based projects that go beyond research to include development activities aimed at transforming research-based concepts into practical forms. Still other government programs extend a project's mission to include production activities aimed at transforming development outputs into finished devices or services (e.g., the Small Business Administration's Small Business Innovation Research [SBIR] and Small Business Technology Transfer [STTR] programs). These programs are typically designed to solve a societal problem where public funding is justified to address issues not amenable to standard market forces. Assistive technology devices for persons with disabilities are such an area requiring government intervention.

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Knowledge Translation, Technology Transfer, and Commercial Transaction

Knowledge translation is entirely appropriate as a strategy for increasing the uptake and use of knowledge outputs from the scientific method. However, it is not the appropriate strategy for communicating knowledge outputs from other distinct yet related methodologies intended to result in beneficial socioeconomic impacts. We have previously suggested that knowledge generated through the research process actually represents only one of three distinct states of knowledge: (1) conceptual **discoveries** generated through research methods; (2) prototype **inventions** created through development methods, and (3) commercial **innovations** manufactured through production methods (Lane & Flagg, 2010). The conceptual discoveries generated through science are recorded in electronic or paper manuscripts and then peer-reviewed and published to become part of the knowledge base. Since conceptual knowledge is amorphous and intangible, it is subject to revision at any time. The findings from further research by the same scholar may alter the claimed discovery, just as other scholars attempting replication may support, refine, or even refute the discovery. Such academic debates are encouraged to keep the knowledge base dynamic and ever advancing.

However, once the focus of government programs shifts from outputs in the form of scholarly literature to technology-based innovations in the marketplace, the relevant models necessarily expand beyond research methods to include both engineering development and industrial production methods. Each of these methods is somewhat codified in its respective literature and practice standards, having its own levels of rigor and relevance appropriate to the state of knowledge. For example, engineering transforms conceptual discoveries into functioning prototypes. Their purpose is to prove that the concept is feasible to construct and operate in a tangible form as well as to establish the parameters in which the concept is likely to function effectively. This transformation is sufficient to prepare claims over intellectual property in the form of an invention, which requires proof of both novelty in the context of prior art and feasibility in the context of natural sciences.

Prototype inventions are built for demonstration purposes only. They may be crudely constructed. They may contain materials or components that would not be practical to include in a finished device due to cost, compatibility, or durability. Because prototypes are physical embodiments of concepts, they are somewhat less malleable than conceptual discoveries, but still have not attained the final form of a commercial device or service. The technology-based knowledge embodied in a prototype invention is the legal intellectual property of the inventor, so freely translating knowledge is no longer the proper strategy. Instead, one applies the process of technology transfer to change ownership and control over the invention from the creator to a party intending to generate a commercial product or service.

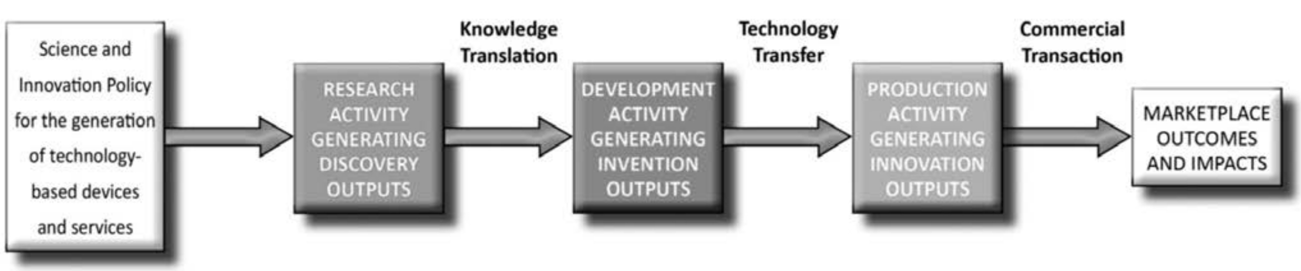
Subsequently, the methods of production are applied to transform the knowledge embodied in the prototype invention into a finished device or service for the commercial marketplace. Production techniques guide the final design of form and function to optimize utility within the contexts of standardization for reliability and mass production for affordability. The final device or service represents a technology-based innovation comprised of conceptual novelty, prototype feasibility, and functional utility. The author views these three elements (novelty, feasibility, utility) as constituting a value-based definition of an innovation, useful for progressively assessing the contributions of sponsored projects to technology-based innovations. Once a final-form product or service is generated, yet another process of effective communication is required, beyond the processes of translation and transfer. This process is the commercial transaction, where the manufacturer receives payment in the form of currency in exchange for a recipient's right to obtain and use the commercial item. Figure 2 depicts the research, development, and production activities in a linear form, along with the respective mechanisms for communicating knowledge to stakeholder groups—knowledge translation, technology transfer, and commercial transaction.

New Expectations Require Sponsors and Grantees to Adopt New Metrics

Government agencies that traditionally fund basic research in the biomedical sciences are often asked to sponsor programs that link research to development, with the expectation that the development outputs (prototypes) will be acquired and applied by manufacturers to generate innovative devices and services (products). But once we decide to integrate the development and production methods into a broader innovation process, are we still talking about the exchange of knowledge between parties? Yes, the novel kernel of knowledge from the original research remains as it transitions from discovery through the other two states of invention and innovation.

Tracking the original discovery as it is reduced to practical form and then incorporated into a

Figure 2: Inputs to Impacts



commercial device or service becomes increasingly difficult, though. To the extent that the technology-based knowledge can be tracked, the original investigators can generate evidence of application and use to satisfy the external program evaluation requirements (U.S. Government Accountability Office, 2004). However, as the kernel of knowledge transitions to prototypes through development methods, and on to proprietary commercial devices and services, the knowledge may be decoupled from the original investigator and sponsor, particularly if they are not actively involved in the transitions through the processes of technology transfer and commercial transactions.

For research and development to generate technology-based innovations, more than one collection of actors is often involved in the process spanning knowledge creation to use. From the point of view of accountability, academic researchers and their sponsors would like to show evidence that the downstream prototypes or products are consequences of their upstream work, and to see an acknowledgment of their contribution. On the other hand, the actors involved in the downstream activities have their own issues and constraints to address that depend on the local context and could not have been anticipated by the researchers. Of paramount importance is for the kernel of knowledge to progress through the chain of stakeholders with the highest probability of success. This result requires all participants to be mindful of the full range of related activities to maximize the facilitators and minimize the impediments to the progression.

While we presume that knowledge exists in any of the three states, the specifics of the communication and exchange process must be adjusted to accommodate the opportunities and constraints related to the knowledge as it transitions from state to state. For example, typically, the exchange of a conceptual discovery requires only that the receivers understand the knowledge conveyed, as they may apply it as they deem appropriate. Thus, knowledge translation is appropriate for this exchange. In contrast, the exchange of a tangible invention as legal property suggests that the receiver will have a specific application for the invention, subject to the constraints of materials, equipment, and expertise. In this case, technology transfer is appropriate to assign ownership over the envisioned application. There is no definitive sequence to the research and development activities, as experimentation and iteration are hallmarks of science and engineering. For example, the replication of a conceptual discovery may require complex experimental arrangements in addition to comprehension of the concept (Callon, 1994).

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The examples of knowledge use in practice, as well as the artifacts resulting from knowledge use, are both considered to be "evidence" that the knowledge has value to society. This evidence is important to government agencies responding to the aforementioned GPRA performance evaluations. The evidence of knowledge use can be documented and then communicated to decision makers. For research programs, such evidence serves to justify both the prior allocation of funds and future budget requests. Research sponsors are keen to have their grantees increase their efforts to track instances of uptake through knowledge translation, technology transfer, and commercial transaction, thereby generating evidence of use and benefit to society. At the same time, the specific case dynamics of use will increase our understanding of the conditions facilitating or inhibiting the translation, transfer, and transaction processes.

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CENTER ON KT4TT

The 5-year **Center on Knowledge Translation for Technology Transfer (KT4TT)** project (**http://kt4tt.buffalo.edu**) was awarded to the University at Buffalo (SUNY), Center for Assistive Technology (CAT) on October 1, 2008. SEDL and Western New York Independent Living, Inc., are partners in the project. SEDL's role focuses on utilization-oriented methods of dissemination, training, and technical assistance to effectively communicate with knowledge producers and knowledge users. This *FOCUS Technical Brief* is a product of the SEDL-KT4TT partnership.

The project focuses on three key outcomes:

- *Improved understanding* of the barriers preventing successful knowledge translation for technology transfer and ways to overcome these barriers
- *Advanced knowledge* of best models, methods, and measures of knowledge translation and technology transfer for achieving outcomes
- *Increased utilization* of these validated best practices by NIDRR's technology-oriented grantees

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