TRACKING EVIDENCE OF KNOWLEDGE USE THROUGH KNOWEDGE TRANSLATION, TECHNOLOGY TRANSFER AND COMMERCIAL TRANSACTIONS

Joseph P. Lane
Center on *KT4TT, University at Buffalo*

RESEARCH VALUE TO SOCIETY

Government agencies sponsor research, 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 and by the general public, to demonstrate evidence showing how outputs from research result in beneficial impacts for society. In the U.S., this scrutiny is grounded in prior law through the Government Performance Results Act (GPRA) enacted in 1993, that holds government agencies accountable for achieving intended results, including programs sponsoring extramural research and/or development activities [1]. The European Commission has faced similar scrutiny regarding the seven Framework Programmes supporting EU international collaborations in technology-based research and development collaborations over the past two decades [2].

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 assumptions. The genesis of this assumption, its consequences and weaknesses were thoroughly analyzed in prior publications [3,4]. 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 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 [5].

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 stakeholders, including knowledge users outside the realm of academe. In the parlance of logic modeling, the research findings are outputs which occur in the short-term at or near completion of the funded research activity. The stakeholder applications are outcomes which occur in the mid-term once 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 socio-economic benefits for society, referred to as impacts [6].

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

From a broader perspective, these measures are recognized as representing the inputs and outputs of a specific project or program. However, they do not represent the outcomes generated through the application of knowledge by non-academics, nor do these 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 entire 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 on-going research [7].

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 [8] 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., NSF's ERC program; NIDRR's RERC program) sponsor technology-based projects that go beyond research, to include development activities where the research based concepts are reduced to a practical form. Still other government programs extend the project's mission to conducting production activities where the development outputs become finished devices or services (e.g., SBA's SBIR and 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.

KNOWLEDGE TRANSLATION, TECHNOLOGY TRANSFER & COMMERCIAL TRANSACTION

For these technology-oriented projects intended to result in a beneficial impact for society, the models appropriate for research-based scholarship are insufficient to address the knowledge outputs from other related methodologies. 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) tangible inventions created through development methods, and 3) market innovations manufactured through production methods [9]. The conceptual discoveries generated through research activities are recorded in electronic or paper manuscripts, then are peer-review 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 the development and production methods. Each of these methods are somewhat codified in their respective literature and practice standards, having their own levels of rigor and relevance appropriate to their state of knowledge. For example, development methods transform conceptual discoveries generated through research methods into operational prototypes. Their purpose is to prove that the concept is feasible to construct and operate in a tangible form, and 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 proof of 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. Since they are physical embodiments of concepts, they are somewhat less malleable than conceptual discoveries themselves, but they have not attained the final form of a commercial device or service. The technology-based knowledge embodied in the prototype invention is the legal "intellectual" property of the inventor, so freely translating knowledge is no longer the proper strategy. Instead one applied 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 methods guide the final design of form and function to optimize utility, within the context 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 authors view 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, the processes of translation and transfer are again insufficient. Instead, one applies the process of commercial translation where the manufacturer receives payment in the form of currency, in exchange for the recipient's right to obtain and apply the commercial item.

NEW EXPECTIONS REQUIRE SPONSORS AND GRANTEES TO ADOPT NEW METRICS

Government agencies that traditionally fund basic research in the biomedical sciences, are now often being asked to sponsor programs that link the research to development, with expectations 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 commercial device or service becomes increasingly difficult. To the extent the technology-based knowledge can be tracked, the original investigators can generate evidence of application and use to satisfy the external program evaluation requirements [10].

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 the investigator and sponsor are not actively involved in these transitions through the processes of technology transfer and commercial transactions.

In these cases of research and development to generate technology-based innovations, there is more than one collection of actors 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 prototype and or product are consequences of their upstream work, and that their contribution is acknowledged. 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 requires all participants to be mindful of the full range of related activities in order to maximize the facilitators and minimize the impediments to 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 presented to the knowledge as it transitions from state to state. For example, typically, the exchange of a conceptual discovery requires only that the receiver understand the knowledge conveyed, as they may apply it as they deem appropriate. Thus knowledge translation is appropriate. In contrast the exchange of a tangible invention as legal property suggests that the receiver to 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 clear 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 additional to comprehension of the concept [11].

Both the examples of knowledge use in practice, and the artifacts resulting from knowledge use, are considered to be "evidence" that the knowledge has value to society. This is important to government agencies responding to GPRA performance evaluations mentioned above. The evidence of knowledge use can be documented and then communicated to decision-makers. For research programs, it serves to justify both the prior allocation of funds and the future budget requests. So, research sponsors are keen to have their grantees increase their efforts to track instances of uptake through knowledge translation, technology transfer and commercial transaction, and thereby generate 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 use through the translation, transfer and transaction processes.

ACKNOWLEDGEMENTS

This is a publication of the Center on Knowledge Translation for Technology Transfer, which is funded by the National Institute on Disability and Rehabilitation Research of the U.S. Department of Education, under grant number H133A080050. The opinions contained in this paper are those of the authors and do not necessarily reflect those of the U.S. Department of Education.

REFERENCES

[1] Office of Management and Budget (1993), *Government Performance and Results Act (GPRA) Related Materials.* [http://www.whitehouse.gov/omb/mgmt-gpra/index-gpra]

[2] See website for European Commission's 7th Framework Programme (FP7) [http://cordis.europa.eu/home_en.html)

[3] Guston D, Kenniston, K: The Fragile Contract: University Science and the Federal Government. MIT Press; 1994.

[4] Stokes DL: Pasteur's Quadrant: Basic science and technological innovation. Washington, DC: Brookings Institution Press; 1997.

[5] Sarewitz D: Frontiers of Illusion: Science, technology and the politics of progress, Philadelphia, Temple University Press; 1996.

[6] McLaughlin J, Jordan G: Logic Models: A Tool for Telling Your Program's Performance Story, *Evaluation and Program Planning,* 1999, 22(1): 65ff.

[7] Canadian Institutes for Health Research CIHR - (2004), *Knowledge Translation Strategy 2004-2009; Innovation in Action*. [http://www.cihr-irsc.gc.ca/e/26574.html]

[8] Graham ID, Logan J, Harrison MB, Straus, SE, Tetroe J, Caswell W, Robinson N: Lost in Knowledge Translation: Time for a map?, *Continuing Education in the Health Professions*, 2006, 26(1): 13 - 24.

[9] Lane JP, Flagg JL: Translating three states of knowledge: discovery, invention and innovation, *Implementation Science*, 2010, 5: 9. [http://www.implementationscience.com/content/5/1/9]

[10] U.S. Government Accounting Office (2004), *Results-oriented government: GPRA has established a solid foundation for achieving greater results.* [http://www.gao.gov/products/GAO-04-38]

[11] Callon M: Is Science a Public Good?, *Science Technology and Human Values*, 1994, 19(4): 395-424.