State of the Science in Technology Transfer

At the Confluence of Academic Research and Business Development –

Merging Technology Transfer with Knowledge Translation to Deliver Value

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Abstract

The practice of technology transfer continues to evolve into a discipline. Efforts continue in the field of assistive technology (AT) to move technology-related prototypes, resulting from development in the academic sector, to product commercialization within the business sector. The article describes how technology transfer can be linked to knowledge translation. The results will increase the relevance of technology-oriented knowledge from upstream academic research to downstream development and production that involve both academic and business sectors. The linkage will provide the government sector with evidence with which stakeholders can apply research knowledge outputs to accomplish outcomes that achieve beneficial impacts for target populations of persons with disabilities. The resulting models, methods, and measures will also be useful to other fields of application.

Key words: Technology Transfer, Knowledge Translation, Assistive Technology, Research Development Production

Overview

The Application of Research and Development to Benefit Persons with Disabilities

In 2008, the State of the Science (SOS) for technology transfer (TT; Lane, 2003) was considering the changing relationships among the three economic sectors that are government, academia, and industry within the AT field of application. Historical relationships resulted from the field's heavy dependence on government support for research and development (R&D) and third-party payment, due to a dearth of market incentives for AT products and services. However, the market conditions are changing as the Baby Boom cohort ages. While the AT field has yet to achieve mainstream status, in the current transition phase companies are ready to consider AT within their seven- to 10-year product planning cycles. Now, more than ever, it is important that federally funded researchers and developers, in academic, government, and corporate laboratories, take into account how their work will (a) transfer to and through industry channels, and (b) benefit end customers.

This paper reviews how product development and TT can be reconciled and merged with the processes of scientific research and knowledge innovation. The academic sector and the government sector, which fund the majority of research, are increasingly aware that the relevance of their results to the industrial sector and their customers is as important as the rigor of their methods. Federal funding agencies and the public expect more accountability on the part of funding recipients to deliver outcomes that impact the target audience. There is heightened expectation for a return on the investment of public funds. The term *knowledge translation* (KT) was coined to represent proactive strategies to communicate research findings to those in a position to put the findings into practice. KT tasks laboratory researchers with ensuring that the new knowledge they produce will be valued and applied by relevant knowledge users (e.g., other researchers, practitioners, policy makers, manufacturers, consumers). This makes KT a great match for TT. New program mandates and federal funding priorities are making this match explicit in practice.

Background

History of Technology and Disability in Government

The National Institute for Disability and Rehabilitation Research (NIDRR) operates out of the Offices for Special Education and Rehabilitative Services (OSERS) within the U.S. Dept. of Education (USDE). The institute manages research, development, education, and training programs related to the needs of persons with disabilities. In fact, NIDRR spends more on disability and rehabilitation than any other federal agency (Brandt & Pope, 1997).

Science and technology. Over the past 50 years, the intersection of scientific progress and empowerment of persons with disabilities generated opportunities for research in disability and technology (http://www.accessiblesociety.org/nidrr.htm). Breakthroughs in biomedical and technological sciences have changed the nature of work and community life. As these breakthroughs provide the potential for longer and more fulfilling lives for individuals with disabilities, they reinforce the second major development: successful independent living and civil rights advocacy by these individuals.

Medicine, technology, and rehabilitation. The field of medical rehabilitation adopted devices to assist patients with recovery and function as early as the Civil War. Advances in manipulation and mobility devices (e.g., wheelchair and prosthetics) moved from low-tech to high-tech throughout the 20th century. Devices to augment sensory limitations followed suit as computer-based technologies in optics, acoustics, and communications also advanced (Mann & Lane, 1995).

AT for independent living. The Independent Living Movement of the 1960s had repercussions for AT. People with disabilities who operated outside of the medical establishment reasoned that their products and services should be generated through the consumer market model rather than through the medical rehabilitation model. They wanted input into the products and services and the delivery systems through which they were acquired. Hence, the oft-quoted motto: "Nothing about me, without me."

The Rehabilitation Act of 1973. At the time of the Independent Living Movement, most federally sponsored research related to disability (a) was addressed by the field of rehabilitation medicine, (b) belonged under the umbrella of the medical model, and (c) was conducted by medically trained researchers sponsored by the NIH. These research programs operated under what the literature refers to as Mode 1 science in which pure, curiosity-driven exploration progresses from theoretical to clinical, or applied, domains (Hessels & Van Lente, 2008).

Public pressure for federal support of studies that were more relevant to the needs of this constituent population, including issues beyond the medical model, prompted the Rehabilitation Act of 1973, a seminal piece of legislation. Among other things, this legislation and its subsequent amendments created NIDRR within the USDE. The language of the Rehabilitation Act of 1973–in response to the social pressures of the Independent Living Movement–was expressed in terms of Mode 2 science (http://www.ed.gov/policy/speced/reg/narrative.html).

NIDRR was charged with accomplishing dual outcomes to improve the quality of life for persons with disabilities by generating (a) conceptual discoveries through research and (b) tangible prototypes through development. This took place prior to the creation of the Small Business Innovation Research (SBIR) program, so the task of generating discoveries and prototypes fell to a new program designed to establish national centers of excellence.

These Rehabilitation Engineering Research Centers (RERCs) were modeled after the National Science Foundation's Engineering Research Centers, but with a focus on a single field of application, i.e., technology applied to the functional needs of persons with disabilities (Carnegie Mellon, the Robotics Institute, Quality of Life Technology Center, 2006) The USDE did eventually create an SBIR program with operational responsibility assigned to NIDRR (i.e., USDE, SBIR program). NIDRR maintains an academic focus through RERCs and an industry focus through SBIRs.

A cascade of empowerment legislation. Advocates equated the independent living philosophy with the civil rights agenda, sparking an array of federal legislation regarding disability rights. The advocacy continues. It has helped bring about periodic amendments to the Rehabilitation Act of 1973, Education for All Handicapped Children Act of 1975, the Technology-Related Assistance for Persons with Disabilities (Tech Act) of 1988, and the Americans with Disabilities (ADA) Act of 1990, the U.S. Supreme Court's Olmstead decision of 1999, and the New Freedom Initiative of 2001 (*Empowering Through the New Freedom Initiative*, 2001). Given the utility of technology-based devices to augment function for people with disabilities, most of these federal acts and decisions included language regarding such devices and services.

Assistive technology defined. The 1988 Tech Act legislation provided the first and only federal definition of AT devices. The definition, while carefully worded, has been misunderstood for years by various stakeholders, including consumers, manufacturers and clinicians. The Tech Act defined both devices and services associated with AT. As such, AT devices are defined thusly: "Any item, piece of equipment, or product system – whether acquired commercially off-the-shelf, modified or customized – that is used to increase, maintain or improve functional capabilities of individuals with disabilities" [29 U.S.C. §3(2)].

Federal definitions used the term *assistive technology* as an adjective and the terms *devices* and *services* as nouns. Since that time, general usage truncated these words into a single phrase. AT has come to refer to either devices *or* services, rather than a specific category of technology-based devices or service. However, technology is not a device. A technology is a form of know-how applied within a specific application. The adjective *assistive* is applied to provide a functional capability to people with a functional limitation within a tangible item, piece of equipment, or product system.

In the context of federally funded research and development activities, grantee research may generate knowledge that can be developed into new technologies (e.g., integrated circuits, storage devices, lasers), or knowledge that can be developed into new products (e.g., personal computer, DVD player, augmentative communication device; Christensen, 2003). Both forms of research and development–federal and grantee–are commonly understood to fall under the term TT, even though the former is actually focused on a technology outcome, while the latter is focused on a product outcome. The imprecise use of words within and across sectors will be shown later to be a barrier to effective communication, particularly in this context.

NIDRR's current mission and role. The creation of NIDRR as a federal research and development program addressing issues of health and function, but established outside of the NIH, demonstrated the government's commitment to supporting the direct application of scientifically derived knowledge to the area of disability and technology. The attributes of NIDRR's mission uniquely position it to address the confluence of research-based KT and development-based TT.

State of the Science in AT TT

In 2003, the RERC on Technology Transfer (T^2RERC) published an SOS in a special issue of the *Journal of Technology Transfer* (Lane, 2003). The SOS addressed neither the entire range of theories nor all facets of practice. Instead, it focused on a sub-set of TT practice concerned with research, development and commercialization of new (or improved) devices and services for people with disabilities: *assistive technology* devices and services.

Looking Ahead from the State of the Science in 2003

The 2003 SOS paper noted that technology transfer was evolving into a discipline. TT was characterized as under-developed because the models, methods, and metrics were not well documented, standardized, nor organized within a theoretical framework. Even the knowledge base underlying the practice was considered to be in the formative stages of development.

As part of the 2003 SOS conference process, conference participants responded to four questions. As a preamble to updates on progress in the intervening five years, those four questions and selected answers from conference participants are paraphrased as follows:

1. What steps are necessary for TT to evolve from a professional practice to an academic discipline?

Research must transform this 'ad hoc' process into something more systematic and rigorous to form the basis for an academic discipline such as knowledge management. TT researchers will probably require a combination of technical skills and applied transfer experience. Research, such as that underway at the T^2RERC, will directly benefit higher learning institutions. For most universities, transfer via formal license agreements is in its infancy, so efforts to study and understand the process will likely have substantial practical value to universities.

Forces driving practices to the level of academic disciplines include a confluence of social groups seeking solutions to unmet needs, practitioners seeking a theoretical framework for guidance, and researchers deciding that the underlying intellectual issues merit study. The field of evaluation grew into a discipline because researchers and practitioners from various fields realized they had common needs and interests. They created affiliations based on this common bond.

Models of technology innovation management are evolving in concert with the latest models of organizational theory. TT is a complex outcome of cultural, market, technical and social forces. Illuminating the process will increase the likelihood of successful technology transfer in the future.

2. The T^2RERC is operationalizing the elements of TT within a valid and reliable process model. What next steps are required to advance the field of technology transfer?

The T^2RERC represents a holistic TT organization, which is rare, if not unprecedented. As the sponsor, NIDRR has provided a unique opportunity to study the process, develop and implement methods, and conduct work across the continuum of TT elements. The next step is to disseminate this information to the broader community of practitioners. However, the absence of an overarching model confines best-practices exchanges to one particular sector. Other sectors won't apply methods and tools until their validity is established.

The field could next expand the research agenda to include empirical testing and documentation of findings from models in practice, to replicate models validated in other fields and to conduct comparative studies of replicated models. Results of this research could be disseminated across disciplines to spread information about the value of the TT process and outcomes.

Literature on the management of innovation offers several models relevant to structuring TT as a formal process. Rigorous data on TT cases should be analyzed through each model to identify their shared and unique contributions to defining a formal process.

Continuing evaluation research is critical to establishing the validity of TT models because valid models are essential to developing the field. Best practices focus on targets and activities that maximize efficiency and effectiveness.

3. How can the T^2RERC's activity further promote mainstream science and technology interest in the field of AT?

To increase federal laboratory involvement, statements of AT needs should be written in terminology that is accessible to scientists and technologists. Needs statements should also describe the benefits that will result from participation. Practitioners are fond of characterizing TT as a 'contact sport' because success requires close collaboration between people from different organizations and sectors. Creating direct linkages between the AT community and federal R&D facilities requires some official status. In other words, it should be a sanctioned activity in terms of advancement and reward in the participants' fields. It should include financial or professional incentives for federal employees who participate.

4. How can the T^2RERC's TT models be implemented to facilitate TT in other industries?

The *supply push* model's market strategy could spark interest in technologies that would fill gaps between available technologies and unmet market needs that are known to product manufacturers. University research faculty members are entrepreneurs in the sense that the availability of funding shapes their research interests, but they are not entrepreneurial in a business sense. A strategic approach requires a TT *office* staff that explores the unmet needs of major product customers, matches available technologies to those needs, and then jointly approaches manufacturers to deliver products that incorporate advanced technologies.

The *demand pull* model requires a sufficient commitment to improve the state of technology supporting the features and functions of a particular product. It is important that programs addressing smaller industries demonstrate the cost effectiveness of a demand pull project and explain how that approach can be applied to other industries.

Demonstrating cost-effective success is the surest way to attract attention from other industries. The total direct cost of each technology commercialized through the SBIR program is $3.4 million (General Accounting Office, 1999). In comparison, each demand pull project costs about $250,000 and generates multiple commercialized technologies. Furthermore, because demand pull projects only target the highest priority needs of each industry, the resulting transfers are both successful and profitable.

Although the 2003 SOS discussion focused on the models, methods and measures of TT, the objective was to improve stakeholders' collective ability to take the outputs from academic research and development activities and apply them in industrial development and commercialization. The whole point of the funding, and of NIDRR's mission, was to generate useful new products and services to benefit persons with disabilities. The pertinent question is: How do we improve that process?

Advances in the SOS 2003-2008

During the five years since the 2003 SOS, the RERC on TT responded to these issues by expanding into a third form of transfer called *corporate collaboration*. In addition to pushing out innovations and pulling in market needs, this approach improves the accessibility and usability of new products that manufacturers have already initiated. These corporate collaborations gather input on product features and functions drawn from populations of people with varied levels of physical, sensory or cognitive impairment. By incorporating the needs of these neglected potential customers at the design stage, the eventual product is useful to a broader section of the marketplace. Just as OXO™ *Goodgrips* broadened the home market for utensils and tools, corporate collaboration is introducing trans-generational products to the marketplace. Mainstream brands like Black & Decker®, Kodak, Tupperware® and Whirlpool® are among the early beneficiaries of corporate collaboration TT. Sales of their products increased due to their improved accessibility and usability for users of all ages and all abilities.

Corporate collaboration reinforced Stephen Covey's philosophy to begin with the end in mind (Covey, 2004). Projects meant to achieve broad impacts in the marketplace should begin with partnerships with the capacity to deliver the end-result to the mainstream marketplace. Meanwhile, projects meant to benefit a subset of consumers should begin with partnerships that are capable of delivering the end-result to the intended beneficiaries. This lesson is equally relevant to the academic and business sectors. Curiosity-driven research conducted in the academic sector has an entrepreneurial element similar to that of exploratory development conducted by independent inventors in the business sector. The utility of both groups' results depends on initiators' knowledge of the current state of the practice and their ability to ensure that stakeholders will value their contributions. At a minimum, basic researchers have an audience of other researchers exploring the same topic; inventors may have an audience of family and friends.

Such local audiences are sufficient for researchers and inventors who are supported by locally obtained resources. However, it is different for those seeking support from venture capital groups or the federal government. The federal government is increasingly interested in accountability among recipients of public funding. It asks the questions long posed by potential investors of private or public funds: What will be the return on that investment? What evidence will demonstrate that beneficial outcomes for stakeholders and beneficial impacts for society are likely?

Such scrutiny requires funding agencies and recipients alike to consider results before beginning a new project with federal support. Accountability standards are becoming stricter for industry development projects that intend to deliver tangible products. Further, the academic sector's standards, which once focused primarily on *rigor*, or research quality, are extending to ensure *relevance*, or the practical utility of the research findings. Balancing the twin standards of rigor and relevance, particularly for projects that combine both research and development methods, requires a new mindset among participants.

Conceptual linkages between TT and KT are becoming clearer. The strategy of linking the two processes may lead to integration of activities traditionally considered separate and distinct.

The following sections provide a brief review of TT followed by an overview of the models, methods, and measures of KT. It concludes with a strategy for integrating them into a single framework.

TT Overview

In the field of AT, there exists between the SOS for TT and the SOS for KT convergent, shared interests. The success of downstream technology transfer derived from development depends heavily on the quality of upstream technology-oriented innovations derived from research. Given the prior discussion of KT, and the relationship between research and development, discussion now turns to an overview of technology transfer concepts and constructs.

TT is a process of transforming an idea for the novel application of a technology into a viable product (Lane, 2003). The TT process arises from any of at least three initiating forces (Rothwell, 1992): (a) *technology supply push*, where new discoveries are offered to the field as opportunities to improve product features and functions; (b) *market demand pull*, where customers define unmet needs as opportunities for new products within specific markets; and (c) *corporate collaboration*, where internal corporate ideas for new products are refined through an iterative cycle of input and feedback from external stakeholders.

The transfer of knowledge into tangible forms is challenging as no path directly connects the source and target audience. Instead, the original discovery has to be transformed through a series of steps. Figure 1 illustrates this transformation through three critical events involving five stakeholder groups (Lane, 1999). The transformation encompasses all activity from the initial conception of an application of knowledge (Idea event), through its embodiment in tangible form (Prototype event) and out to commercial production (Product event). The entire TT process is preceded by various activities under the heading 'Research,' and is followed by various activities under the heading 'Production.' The majority of the TT process falls under the heading 'Development--hence, the Research, Development, Production (RDP) model.

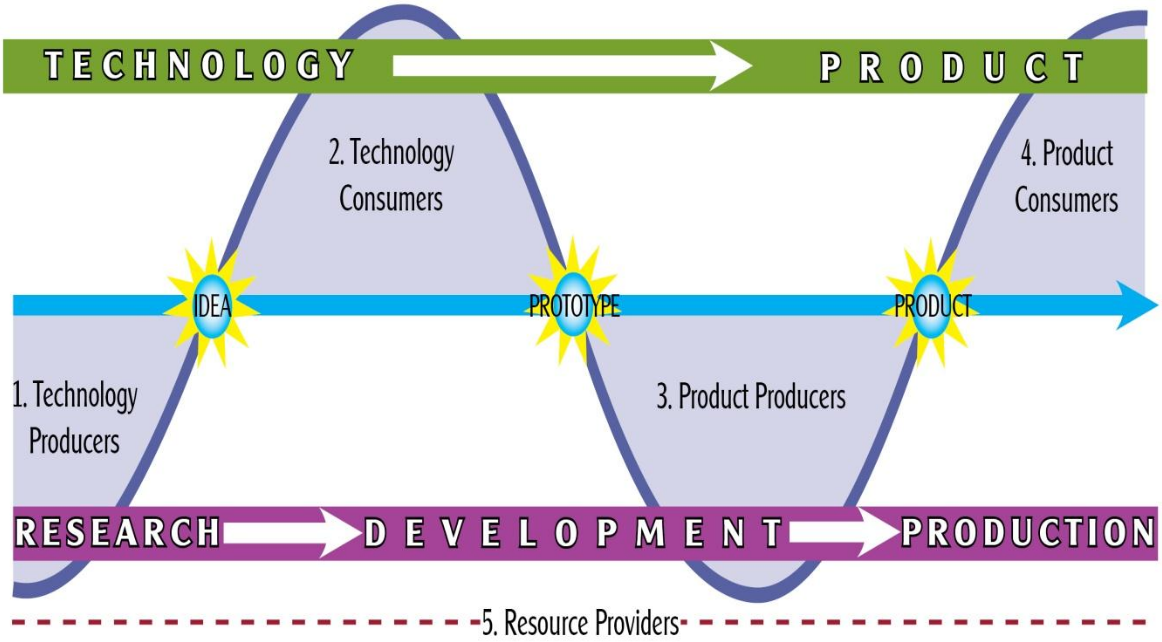

Figure 1. A composite model of technology transfer elements.

It is important to note that the five Stakeholder groups involved in the TT process overlap with the set of five User categories involved in the KT process. Manufacturers and Brokers-Users--are directly engaged as stakeholders under the 'Technology Consumers' and 'Product Producers' headings. The User category, Other Researchers, typically engages in the preceding Research section, called 'Technology Producer' stakeholders. The User categories Clinician/Practitioner and Consumer are typically engaged in the subsequent Commercialization section, called 'Product Consumer' stakeholders. However, representatives from all User categories may provide input throughout the Development process. User categories Brokers and Public Policy are each part of the 'Resource Providers' stakeholder group.

Figure 1 demonstrates how research-based knowledge about various technologies and their possible applications culminates in the *idea event*–the articulation of a specific application of a specific technology. Development activity ensues to transform the idea into the first tangible and functional form–the *prototype event*. The prototype demonstrates that the application idea is feasible in a practical form. Further development ensues, turning the prototype into a set of designs and specifications for a product. The first copy of the final design to roll off the assembly line is the *product event*. TT practices focus on the area in the process between the idea event and the product event. This area of development is where the conceptual value of knowledge under the control of the research innovator is transferred to manufacturers' control where its value takes product form and becomes tangible.

Development activity progresses through a sequence of focused activities called steps. The Product Development Managers Association (PDMA) recently published the second edition of a textbook, along with a three-volume toolbook series, characterizing the contents of any new product development process (Belliveau, Griffin, & Somermeyer, 2007; Kahn, Castellion, & Griffin, 2005). The author extracted and ordered a series of 20

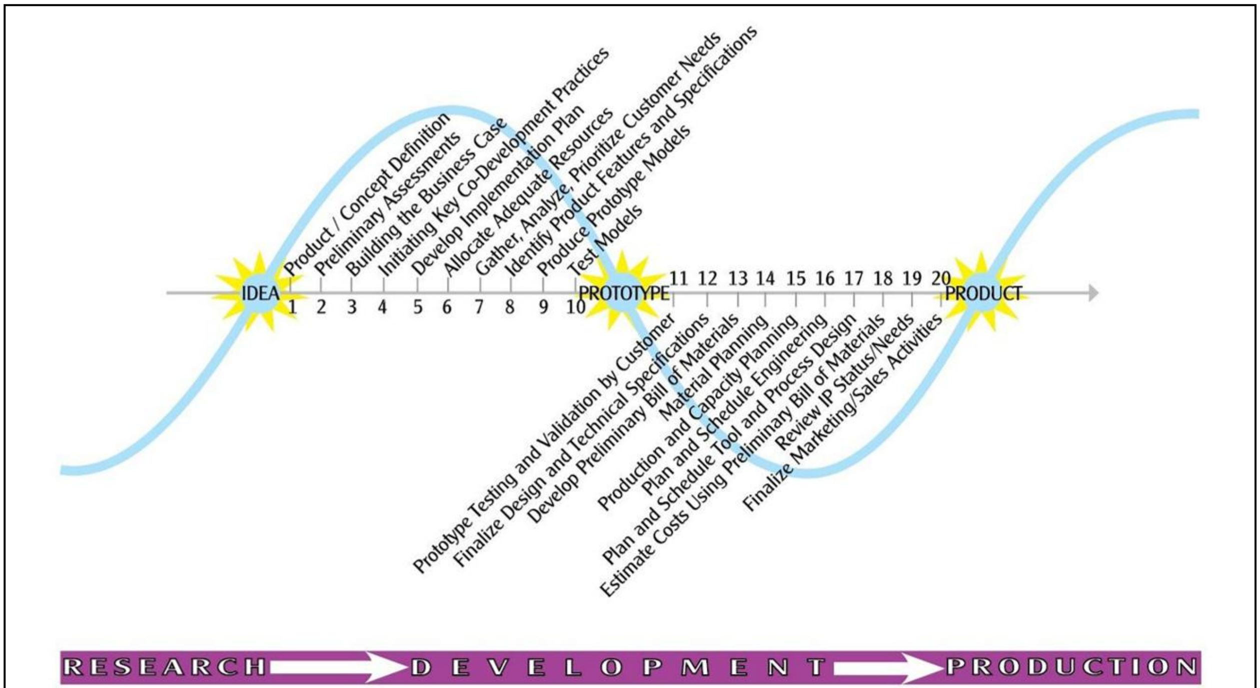

Figure 2. The PDMA 20-step product development process.

steps that represent the minimum range of activities required to advance a project from the idea event to the product event. A chart of these steps was compared with another framework in the literature to verify their order and content (PHAE Group, n.d.). Overlaying these 20 steps on the technology transfer figure resulted in the map shown in Figure 2.

Management science literature studies the practices required to accomplish these 20 steps. The literature is also a resource for identifying and categorizing any barriers to progress and ways to avoid or overcome those barriers. Figure 2 shows the 20-step development process as linking research to production. This corresponds to the definition of KT as encompassing all steps between the creation of new knowledge and its application to yield beneficial outcomes for society (Canadian Institutes of Health Research, n.d.). Each step in the product development sequence has its own input, process, and output tasks. The fundamental work of creating an operational model of KT, in the context of the operational model of technology, will occur at these levels of steps and tasks.

KT Overview

Origins of KT

KT is the bridge between research discovery and societal impact (Graham, 2007). The knowledge production system–particularly in the area of health research–is adopting KT theory and practice as a means to increase knowledge utilization. This includes efforts to increase the impact on society of technology-based knowledge via new products and services.

Canadian Institutes of Health Research (CIHR). The CIHR was created in 2000 with a mandate for "the creation of new knowledge and its translation into improved health care for Canadians, more effective health services and products…" (CIHR Research Act, 2000, p. 7). The CIHR generated immediate international interest by coining the term KT.

While CIHR's definition of KT continues to evolve, the institute currently defines it thusly: "Knowledge translation is a dynamic and iterative process that includes synthesis, dissemination, exchange and ethically sound application of knowledge to improve the health of [citizens], provide more effective health services and products and strengthen the health care system" (CIHR, n.d.).

The CIHR's first KT model overlaid a traditional linear model of research progression, running from idea conception to contribution to the global knowledge base (CIHR, 2008). The opportunities to apply KT within the standard cycle of scholarly activity were indicated in six places (see Figure 3).

Within the CIHR model, two knowledge-translation opportunities (KT_1, KT_2) fall within the research process itself. Researchers, therefore, could increase translation opportunities by involving stakeholders in the design and research. This principle was previously espoused under the title 'Participatory Action Research' (see discussion of KT-related concepts below; Whyte, 1991).

The CIHR overlay shows that opportunities to practice KT did not end at their contribution to the global state of knowledge. The researcher had two options for moving the knowledge to potential user groups. Both are conceptual in nature, which is appropriate given that researchers are not expected to apply their findings.

One option, KT_3, involves knowledge dissemination. The traditional dissemination path for research outputs involves sharing new knowledge with other researchers in the same field through the journals and conferences established for that very purpose. The KT_3 approach expands dissemination to

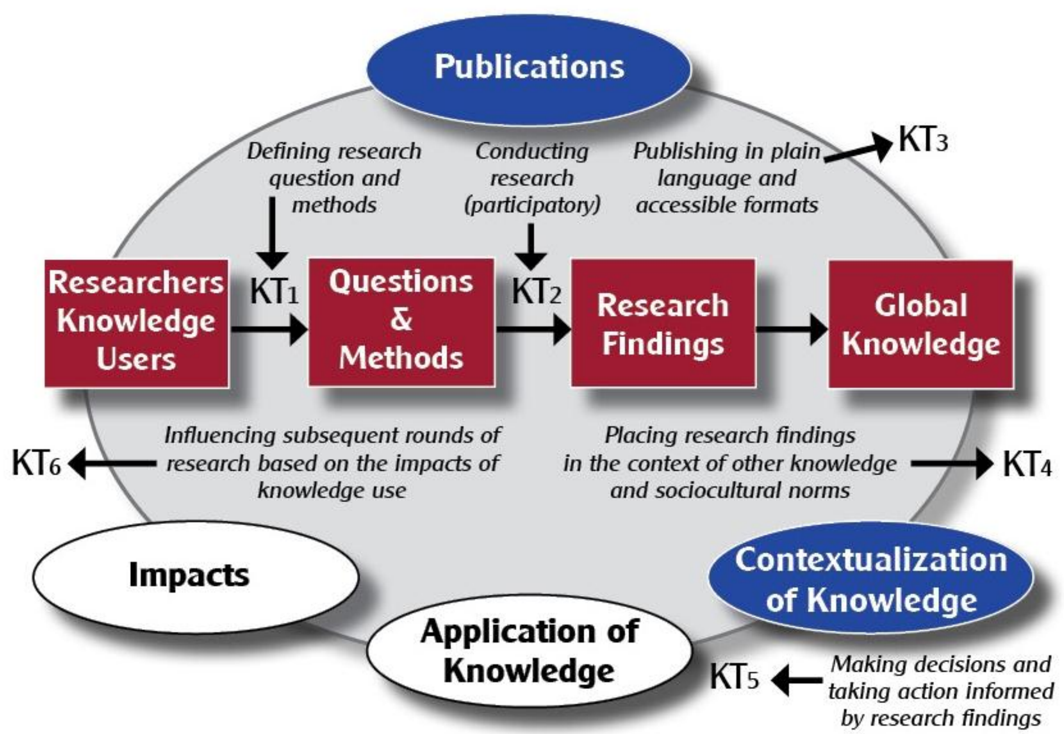

Figure 3. CIHR model of KT.

other target audiences. Doing so requires tailoring the form and content to that audience, which assumes a researcher will devote time and attention to understanding that audience's needs and interests. One might convey this distinction by modifying the diagram so that there are multiple arcing lines between the Global Knowledge box and the Publications oval, thus signifying multiple dissemination paths.

The other option, KT_4, involves knowledge contextualization. Science has limited experience with contextualization, as the traditional role calls for objectivity characterized by an independence from context (see discussion of Mode 1 vs. Mode 2 science). The KT_4 approach requires researchers to become involved with various stakeholders, at least to the extent that they help stakeholders apply the knowledge. The diagram could be altered in a similar fashion to show multiple arcs between the Global Knowledge box and the Contextualization oval, given that knowledge can likely be applied to a variety of contexts. Two shaded ovals in Figure 3--labeled 'Publication' and 'Contextualization of Knowledge'--are the options for the application of new knowledge which are directly available to the researcher as the knowledge producer. The two ovals labeled 'Application of Knowledge' and 'Impacts' require actions by some external stakeholders as the knowledge users, who are beyond the direct control of the knowledge producer. This point is expanded in Figure 4 below.

The two options available to knowledge producers for communicating any new discoveries both require them to operate outside their traditional academic networks. The CIHR calls the KT_1 and KT_2 approaches *integrated KT* because they engage stakeholders from the inception of the research project and involve them in all phases. The familiarity that comes with early involvement simplifies the later dissemination and contextualization. CIHR calls the KT_3 and KT_4 approaches 'End of Grant KT' because the researcher creates a plan to share research findings with the appropriate target audiences but only after the work is completed. The end of the grant approach requires an assumption regarding the actual utility of knowledge outputs to the target audiences, which can only be validated once potential users apply the knowledge.

Opportunities KT_1 through KT_4 were largely investigator-initiated, although any group of stakeholders could approach a researcher about establishing such a relationship. The final opportunity, KT_6, falls within the same conceptual mode, where the researcher examines the evidence of impacts and consequences, and applies them to future research. KT_5 differs from the others in that it represents instrumental rather than conceptual activity (see discussion of forms of use below). Research-based decisions and actions can take many forms. The remainder of this paper will focus on decisions and actions related to knowledge outputs about technologies in the context of accomplishing TT outcomes.

The Application of Knowledge oval within the CIHR diagram represents an extensive, complex range of activities. It is important to note that researchers are not compelled to independently perform the full range. However, if they conducted sponsored research that comes with an expectation of public benefit, they should know enough about the entire process to ensure they facilitate progress through to beneficial impacts. Likewise, they should do nothing to hinder that progress by other stakeholders.

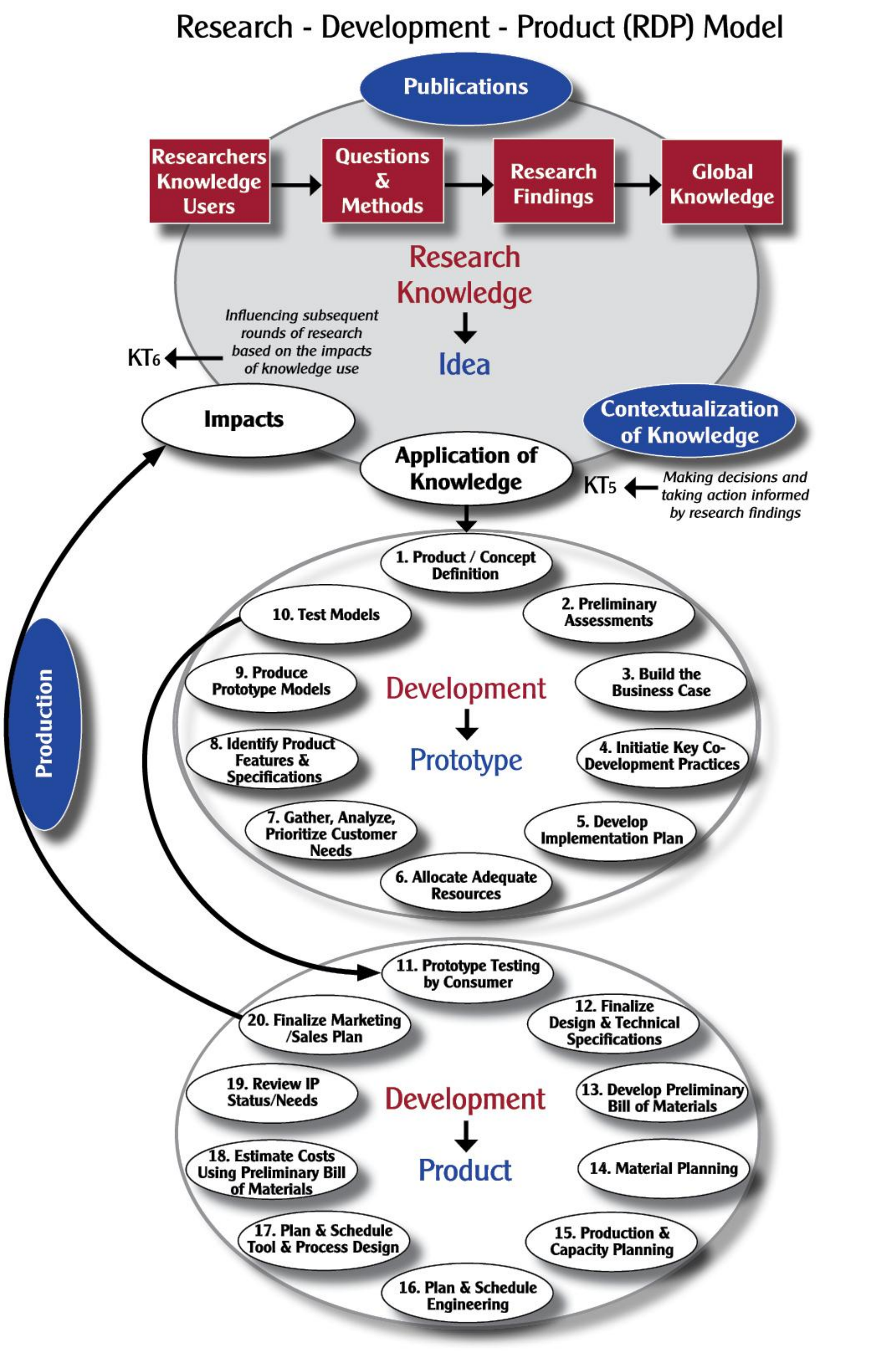

Figure 4. RDP model.

This paper provides additional details to illustrate the extensive and complex range of activities that must occur to bridge research to impact by adding two additional cycles of activity to the CIHR's original diagram in Figure 3. In Figure 4 these two additional cycles represent the 'Action' portion of the TT process, which follows a knowledge user's decision to acquire and apply the research-based knowledge in the tangible form of a product. Figure 4 shows these two linked cycles as white ovals to link them to the white ovals from Figure 3. The RDP model also adds one additional shaded oval labeled

'Production' to represent the replication of the new product or service in their final form. The final form is what reaches the intended beneficiaries and what actually generates the impacts suggested in the last white oval under the CIHR model. This extended diagram is called the Research/Development/ Production (RDP) model, because it expands the Application of Research Knowledge oval into a Prototype Development cycle and a Product Development cycle.

The traditional scholar may believe that the majority of the effort is accomplished once new knowledge is generated through research methods. However, the RDP model shows how much 'end-of-grant' effort is required to transform conceptual knowledge into a tangible product or service. The scholar's success at enlisting other stakeholders to conduct this additional work is directly related to the perceived utility and value of the eventual outcome to these same stakeholders. The transition from conceptual knowledge requires the communication of benefits to target audiences requires the methods reflected in the KT model. Meanwhile instrumental application, in the form of devices or services, requires the methods listed in the RDP model. The latter is described in terms of product development steps in the context of the TT model.

Other KT definitions. The CIHR is not the only organization to define KT (Graham et al., 2006). European governments are pursuing similar strategies. The U.K. Medical Research Council (2007) held a workshop on 'Accelerating the Translation of Medical Research,' which articulated a need for "cultural change within the research community and recognition that translation of research findings and communicating findings to research users was part of a researcher's role." The Netherlands Organization for Health Research and Development recently published a guide to Knowledge Synthesis to promote the use of knowledge in policy and practice (Bos & Van Kammen, 2007).

These international efforts focus on moving knowledge from the production system to the user system for public benefit. The shared focus on beneficial impacts means that KT in word must be matched by KT in deed. In response to this heightened focus on action, the CIHR is implementing the Knowledge to Action (KTA) model, described in detail below. These models show how the KT concept applies to the traditional research paradigm. KT's models, methods and measures are still evolving, as are its relationships to the traditional development paradigm.

Related Activities in the U.S. Federal Government

NIH roadmap for medical research. The NIH Roadmap for Medical Research (National Institutes of Health, 2008) was implemented in 2002. The process involved identifying major opportunities to advance biomedical research and address major gaps in the knowledge base that no single NIH institute could address alone. Instead, the NIH would address these opportunities and gaps at the institute level in conjunction with government, academic and private sectors. The purpose is to accelerate advances in medical research at a scope of complexity and scale of application to profoundly impact the health and welfare of humanity and society.

The NIH roadmap process identified three themes relevant to KT for TT:

1. *New pathways to discovery.* This intends to create a better 'toolbox,' including access to technologies, databases and other resources that are more sensitive, more robust and more easily adaptable to researchers' individual needs.

2. *Research teams of the future.* This encourages scientists and scientific institutions to test alternative models for conducting research, including: interdisciplinary research that links the physical and biological sciences, high-risk and high-return investigations and public-private partnerships that accelerate the movement of research discoveries "from bench to bedside."
3. *Re-engineering the clinical research enterprise.* This accelerates the transformation of research discoveries into drugs, treatments, interventions, and devices. The results are to simultaneously support evidence-based practices and improve the knowledge base.

The NIH roadmap indicates how the academic research sector strives to balance the rigor of Mode 1 science with the relevance of Mode 2 science. The role of Mode 1 science is well established, as are the underlying models, methods and measures and the peer-review standards by which scholarship is valued in academia. Science conducted within the context of application, or Mode 2 science, brings a different set of constructs and expectations (Nowotny, Scott, & Gibbons, 2001). Three examples include that applied science (a) is holistic rather than reductionist, requiring interdisciplinary approaches to complex issues (Giacomini, 2004); (b) requires collaborations with non-academic stakeholders and even target users' audiences to ensure relevance (Denis & Lomas, 2003); and (c) holds that discoveries are a means to the end of knowledge use in practice or policy (Canadian Health Services Foundation, 2000).

Mode 2 science is not readily or easily valued under traditional Mode 1 standards, but it is more readily embraced by the relevant stakeholders and by the general public (Phaneuf, Lomas, McCutcheon, Church, & Wilson, 2007). The NIH Office of Behavioral and Social Sciences Research succinctly framed the problem and solution on behalf of the basic (Mode 1) and applied (Mode 2) science funding through all of the NIH institutes (U.S. Department of Health and Human Services, 2007): "How can we strengthen the science of dissemination and the dissemination of the science of behavior change?" (p. 5).

In 2000, the same year the CIHR was established in Canada, the U.S. Agency for Healthcare Research and Quality established the "Translating Research into Practice Initiative" because:

> Translation of research findings . . . remains a substantial obstacle to improving the quality of care. Up to two decades may pass before the findings of original research become part of routine clinical practice. [This] initiative focuses on implementation techniques and factors associated with successfully translating research findings into diverse applied settings. (Agency for Healthcare Research and Quality [AHRQ], 2001, para 1)

The sectors, organizations and individuals responsible for improving our quality of life seem united on the importance of increasing the translation and utilization of research by knowledge user groups as a means to increase the beneficial impacts of this work.

OSERS/NIDRR principles and practices. In the early 1990s, NIDRR's new leadership was appointed from the community of persons with disabilities. The director of NIDRR and her supervising director of OSERS were both consumers, as well as advocates, for their respective constituents. Thus, they witnessed and experienced the lack of engagement between researchers and the public, which was particularly irksome in programs designed to address the needs of people with disabilities. Having grown up in the

Independent Living Movement, these leaders approached the federal government determined to increase the research culture's responsiveness to their constituents.

The changes were couched in several principles and practices. NIDRR had sponsored national centers of excellence on technology evaluation and TT since the 1980s. However, from the early 1990s onward, NIDRR focused these centers' work on moving technology discoveries and prototype inventions to the marketplace. At the same time, NIDDR introduced the principle of participatory action research by encouraging all grantees to integrate people with disabilities into each phase of their research and development. The NIDRR established another national center in the mid-1990s to increase grantee focus on knowledge dissemination and utilization activities. Recognizing that KT encompasses these dissemination and utilization activities, NIDRR recently redefined that center's mission to address all aspects of KT (National Center for the Dissemination of Disability Research, n.d.).

Converging interests in knowledge production systems. As noted previously, government is increasingly interested in boosting societal return from its investment in research. Society has a say in the role of science--at least in the portion of science sponsored by a publicly funded government. One example is the recent debate over federal support of stem cell research. However, the role of science in society appears to be changing at an even more fundamental level. The traditional paradigm of scientific research is theoretical, discovery-oriented and curiosity-driven (Mode 1; Knorr-Cetina, 1999).

Tensions between Mode 1 and Mode 2. A recent paper by Kitson and Bisby (2008) recounts an interdisciplinary body of literature, which articulates fundamental change in society's perception of research and knowledge production. To wit, Mode 1 science and its practitioners are increasingly challenged to engage in Mode 2 research or at least collaborate with Mode 2 researchers (Kitson & Bisby).

Supporting evidence comes from three sources: (a) public policy that steers scientific research priorities toward programmatic, relevant, collaborative and cost-effective projects (e.g., Human Genome Project); (b) funding allocations that are driven by the commercial potential of new discoveries rather than as contributions to the public knowledge base (e.g., patent protection and licensing revenues); and (c) increasing accountability of science to society in terms of resource management, project deliverables and measurable benefits (e.g., Nowotny et al., 2003; Office of Management and Budgets' Program Assessment Rating Tool).

The point is not to consider the relative merits or possible synergy between Mode 1 and Mode 2 science, nor to debate the role of science in society. The interplay of government, industry and academia has been studied intently (Bransomb & Keller, 1998). The point is to ground NIDRR's current problem within the context of the current social expectations facing all science--particularly publicly funded projects. All science is being held accountable in various new ways. The Mode 2 science designed for application--such as that conducted by NIDRR's technology grantees--is logically subjected to the most intense scrutiny at the formative and summative levels. Given the national and even international nature of this social shift, NIDRR had the luxury of seeking possible solutions to its problem in work already underway elsewhere.

By definition, Mode 2 science should demonstrate evidence of science-based knowledge applied within some context external to the production of that knowledge. Application requires action by actors. Action requires actors to expend resources on that application task. All resource allocation decisions represent commitments from actors to accomplish a course of action, presumably to receive personal or professional reward. Researchers and their funding agencies must ensure that knowledge outputs will be applied by stakeholders, who will otherwise question the purpose of the research. Once applied, the knowledge should generate positive impacts for the intended beneficiaries and possibly for unintended beneficiaries. Of growing concern to NIDRR and to government research sponsors globally is the need to increase the diffusion of knowledge produced by knowledge producers and to thereby increase the outcomes generated by knowledge users.

In summary, now that federal agencies in Canada, America and elsewhere are looking to apply sponsored research outputs whenever and however possible, the early NIDRR practices are coalescing around this KT concept. This focus opens new conceptual frontiers for NIDRR, their grantees and all stakeholders involved in the field of AT.

Theories of KT

A *theory* is a systematic rendering of ideas, concepts or principles along with the causal or associational relationships among them (Jacobson, 2007). The literature claims that no satisfactory overarching theory for KT exists in the health sciences. An established KT theory is essential for designing testable and likely useful interventions, but none of the models in organizational innovation (Grol, Wensing, & Eccles, 2005), nor in social science literature (Weiss, 1979), appear to offer a solution. Instead, some authors call for combining multiple theories from various disciplines to address the range of practice settings into which research findings must be translated. They liken theories to maps which are specific to a geographic area--the more specific the map (theory), the more useful for negotiating the terrain (context). A range of theories from multiple disciplines is required to address user categories at all the levels and types of use (Estabrooks, Thompson, Lovely, & Hofmeyer, 2006).

The roadmap analogy seems apt and can be expanded. Maps are most useful when one knows the starting point and the intended destination. Advance knowledge of the terrain and identifiable landmarks help to keep a journey on course and on time. In this context, it is important to identify and synthesize the KT models most relevant to accomplishing technology transfer outcomes, and to refine the KT concepts in operational terms appropriate for TT. This includes refining the KT methods in operational terms.

The two major landmarks on this particular map are the domains of the Knowledge Production System (KPS) and the Knowledge Utilization System (KUS). Both the KPS and KUS operate at the levels of individuals, organizations and sectors. Recent literature emphasizes the importance of exploring utilization at the multiple levels of each system: "These levels of analysis influence each other and cannot be disassociated" (Belkhodja, Amara, Landry, & Ouimet, 2007, p. 380).

Knowledge Production System

The knowledge production system consists of elements operating at the sector, organization, and individual levels. Although KT originated outside the U.S., the examples here focus on U.S. organizations for domestic readers.

Sector. This level includes government, industry, academic and civic sectors, each representing groups of organizations, their inter-relationships and the societal context. The government level includes all publicly sponsored agencies conducting research and development. This sector includes all cabinet-level departments (e.g., Education, Health, Commerce), related agencies (e.g., NSF, NASA) and the network of mission-oriented government laboratories. They all sponsor intramural research and development.

Organization. At this level, sector-level entities sponsor extramural research and development through subsidiary organizations (e.g., NIDRR, NIH, NIST). Sponsoring organizations interact with the sponsored programs at the organizational level (e.g., universities, corporations). Each organization encompasses all internal personnel, resources and capabilities.

Individual. The sponsored activity at this level is conducted through grants, contracts or cooperative agreements conducted by individual project directors as technology grantees. NIDRR's technology grantees in the three selected technology areas are a sub-set of all NIDRR grantees as noted above.

Knowledge Utilization System

The sector, organization, and individual levels of knowledge users are also described using U.S. examples.

Sector. The societal sectors of civil, government, industry and academia all contribute to the quality of life for people in general. Also, at this level, the health-related components of each sector are particularly concerned with the quality of life for persons with disabilities.

Organization. In each sector there exist organizations that focus on health and function as it relates to people with disabilities. For example, the Assistive Technology Industry Association represents manufacturers of products for use by people with sensory or cognitive impairments. Meanwhile the American Association for Homecare represents manufacturers of technology-based devices that are acquired through third-party reimbursement (e.g., wheelchairs, respirators, prosthetics). Professional associations exist for physical, occupational, speech and respiratory therapy. Consumer associations have been instrumental in enacting empowerment legislation that emphasizes quality of life for persons with disabilities.

Individual. NIDRR staff recently published an article describing four categories of knowledge users (the first four in the list below) at the individual level (Sherwood & Melia, 2007). The author adds two additional categories of knowledge users (the final pair in the list below), which are particularly relevant to the field of AT. Here is a listing of the six categories:

1. *Other Researchers*--The academic structure encourages knowledge exchange through publications, conferences and collaboration.
2. *Practitioners, Clinicians*--These are physicians and nurses, for example, who are subjects for much KT research, as well as therapists, counselors and rehabilitation engineers.
3. *Policy Makers*--These public- and private-agency representatives apply evidence-based knowledge to establish programs, protocols and reimbursement levels.
4. *People with Disabilities*--Members of this category use knowledge to manage their own access to products and services, as well as to advocate for change.
5. *Manufacturers, Suppliers*--This category includes original equipment manufacturers (OEMs) and value added retailers (VARs) who perform the production, distribution,

marketing, sales and support of devices and services after TT occurs.

6. *Brokers*--These are typical legal, marketing or technical professionals who protect, disclose, market and sell rights to use innovations created by others. Universities operate technology transfer offices (TTO); federal laboratories operate offices of research and technology administration (ORTA); and corporations contract with law firms.

Knowledge User categories are described only in terms of those with direct relationships to the field of AT. A parallel set of potential Knowledge Users with indirect relationships to the field also exists. For example, Other Researchers in the field of robotics identified, adapted and used research discoveries generated by the research on prosthetics and orthotics. They applied discoveries regarding the biomechanics of a 'shape-and-roll' artificial foot to the gait of robots. In this case, knowledge users from outside the AT field actively sought and used knowledge that was generated and disseminated only within the AT field. The indirect relationships are too numerous to recount here, but their presence is a reminder that knowledge users are not restricted to those participating directly in any particular field of application.

Three KT theories--called *meta-narratives*--explain how the KPS and the KUS systems interact (Greenhalgh, Robert, Macfarlane, Bate, Kyriakidou, & Peacock, 2005):

Meta-Narrative 1: Spreading beneficial ideas through practice networks. This theory follows the sociological explanation underlying the diffusion of innovations. Useful new knowledge is interjected into a social system and gains influence through personal and organizational contacts. The key is that the network is comprised of practitioners so all have a vested interest in applying new tools or techniques through a peer-to-peer process. This is an emergent, ecological paradigm particularly appropriate for naturally occurring social networks.

Meta-Narrative 2: Evidence-based methods and practices that are delivered to practitioners. This is called *rationalistic theory* because management identifies demonstrably superior approaches in the external environment then mandates adoption of the new approach to the internal organization. The logic follows that any innovation is adopted with alacrity for the simple reason that the evidence shows it to be superior. This is an organizational-management paradigm most appropriate for hierarchical systems where rewards follow compliance.

Meta-Narrative 3: Knowledge utilization as an organizational capability. This theory operates independent of external factors because the form and function of knowledge is assumed to change as it moves between organizations and across intra-organizational levels. The knowledge in its external or transitory forms is less important than how the knowledge moves within an organization and supports organizational functions.

All three meta-narratives address the context of knowledge use and the intent of the users, who reside within the individual knowledge users and their organizations (Estabrooks, 1999). Understanding content and intent requires the KPS to examine the KUS to understand the: (a) circumstances and contexts in which new knowledge could be applied, and (b) values of target audiences, which will shape their perceptions of knowledge utility.

Despite the three levels at which KPS and KUS operate, these theories suggest that successful application of KT requires producers to thoroughly understand users at the micro-level of individual adopters.

Models of Knowledge Communication that Inform KT

A *model* represents a theory or a set of concepts and their underlying relational structures (Jacobson, 2007). The conversion and communication of knowledge from one system to another has been modeled in the literature under many terms. Here are four: *innovation diffusion*, *knowledge transfer*, *knowledge use* and *research knowledge utilization* (Bzdel, Wither, & Graham, 2004).

Diffusion of innovations. Some scholars view the *diffusion of innovations* as the closest thing the field of KT has to a reference theory (Estabrooks et al., 2006). Diffusion research began in the field of rural sociology with a study of how the use of hybrid seed corn (an innovation) migrated to Iowa farmers (Ryan & Gross, 1943). The results of this and subsequent sociological studies showed that innovations are communicated through social networks over time and that the rate of adoption typically follows an s-curve. The s-curve results from variations in the speed at which members of the social network adopt or decline the innovation. Users typically fall into five adopter categories derived by laying off standard deviations from the average time of adoption: (a) Innovators (2.5%); (b) Early Adopters (13.5%); (c) Early Majority (34%); (d) Late Majority (34%); (e) Laggards (16%) (Rogers, 1995).

Knowledge transfer. This model considers a variety of methods for communicating knowledge from a source to a target audience. The primary methods are dissemination or education and or training. It means more than publication. Dissemination includes efforts to synthesize research findings and tailor the resulting message to an intended target audience. These steps are deemed necessary as many potential users are not trained to critically appraise and apply research findings (Lomas, 1993). The methods may be applied individually or in combinations. Studies indicate that knowledge transfer methods offer modest to moderate improvements in knowledge implementation when applied as single interventions, although the relative effectiveness of each strategy varies with the circumstances surrounding application (Grimshaw et al., 2004).

One of the only studies on this topic evaluated changes in knowledge and practice among health care workers (Heinemann, Roth, Rychlik, Pe, King, & Clumpner, 2003). The study found that clinicians with the least knowledge are the least likely to cooperate with an education/training program. Of course, their attitudes may determine their low knowledge levels. Clinicians' pre-training knowledge levels, and their readiness to change, are key indicators of the need to put successful knowledge transfer into practice.

The concept 'readiness to change' is a topic of research (Dalton & Gottlieb, 2003). Much of the work focuses on changing the behaviors of patients or clients, who risk suffering serious consequences from their current behaviors (e.g., risk of stroke; Miller & Spilker, 2003); substance abuse (Prochaska & D'Clemente, 1993); and inappropriate behaviors (Rosenbaum, Frankes, & Jaffe, 1983). Despite seemingly high motivations to change, high incentives from current behaviors create resistance to change. Contrast this to *readiness to change* in situations where motivations for change and incentives to resist change are both fairly low. It may be difficult to motivate change when the expected results hardly overcome the inertia of habit.

The Concerns-Based Adoption model (CBAM) is a well established conceptual framework that describes, explains, and predicts probable behaviors in the change process. Its design encourages modifications that fit individual situations (Hall & Hord, 2006).

The three principal diagnostic dimensions of the CBAM are: (a) stages of concern (i.e., seven different reactions that people experience when they implement a new program); (b) levels of use (i.e., behaviors people develop as they become more familiar with, and more skilled in, using an innovation); and (c) innovation configurations (i.e., people adapt innovations differently depending on their situations).

Knowledge use. Conceptual models of knowledge use are as varied as the fields, actors and contexts in which the use occurs. Three basic dimensions of knowledge use models are identified (Dunn, 1983): (a) composition, i.e., distinguishing between individual use for decision-making, and collective use for edification; (b) expected effects, i.e., may be individual or collective but expected effects differ by whether use changes the user's understanding of a situation or changes a user's behavior in response to a situation; and (c) scope, i.e., concerns the processes involved in use in terms of their generality such as a heuristic, or specificity, in terms of protocols or guidelines.

Any combination of these three dimensions can define knowledge use, as when decision-based actions are specific, individual and behavioral. These three dimensions are foundational and remain apparent even in the more refined constructs that follow.

Research Knowledge Utilization

The use of research knowledge is treated as a specific form of knowledge use. In research knowledge use, empirical findings from one or more studies combine to substantiate a decision, intervention or policy (Estabrooks, 1999). Analysis of the potential public benefits from social science research defined three forms of research knowledge use (Weiss, 1979):

1. *Knowledge-driven* use--This is a linear process where basis research results are identified as relevant to a public need. These results are tested for applicability. If the results demonstrate applicability, an appropriate device or service is created and applied. This model represents the Cascade model (Mode 1) of science and therefore represents the operating premise of most university-based technology transfer offices (Tornatzky, Waugaman, & Gray, 2002). The outputs from research are viewed as contributions to the global knowledge base, while applications are secondary outcomes.
2. *Problem-solving use*--This is the opposite circumstance. In problem-solving use, a public need for information initiates the design and conduct of a research study. This is another linear process where a lack of information prompts research and the resulting knowledge is applied. This model represents the Applied model (Mode 2) of science. It is the operating premise of most contract research and the mission-oriented Federal Laboratory Consortium for TT (FLC). People who rely on this model expect research to be problem-driven, and they criticize Mode 1 science that fails to demonstrate social relevance.
3. *Interactive use*--This is a non-linear network of relationships between knowledge producers, user and intermediaries. Existing research-based knowledge is viewed as one input to public issues. It may be combined with newly commissioned research on a given topic. *Interactive use* generates the

greatest tensions between Mode 1 and Mode 2 science.

Taken together, the four preceding models, diffusion of innovations, knowledge transfer, knowledge use, and research knowledge utilization, represent a historical progression (maturation) with respect to knowledge valuation and use over time (Landry, Amara, & Lamari, 2001). They represent the formative stages of KT model development, which is discussed in the next section.

KT Models

This KT overview has described CIHR's role in establishing the field of knowledge translation and articulating KT's first model. As a health research organization, CIHR first drew lessons from, and applied the KT model to, biomedical contexts where the producer and user systems were already closely linked (Sudsawad, 2007). Physicians and nurses working in medical facilities operate within tightly scheduled, highly regimented and thoroughly documented environments. Implementing KT systems to change practices within these closed environments (or systems) is somewhat akin to working within a controlled laboratory. For researchers, it's an ideal setting in which to pre-test, introduce interventions and post-test. Changes in attitudes, behaviors and clinical outcomes are fairly strong indicators of the intervention's effectiveness.

New drug development involves collaboration among academic, corporate and government laboratories. These entities work together to rapidly move discoveries to the marketplace. This was another situation with near-laboratory conditions in which interventions could be tested.

These conditions led to the creation and exploration of numerous models, including the Stetler, PARiHS, Ottawa, 10 Stage, and Knowledge to Action model (Kitson & Bisby, 2008). These models share many important elements. The models differ more on emphasis than on content. They have collectively contributed to the creation of the KTA (Graham et al., 2006). The CIHR focuses on the KTA model. Given CIHR's leadership in the field, the SOS also focuses on the KTA model (Tetroe, 2008).

Focusing on the KTA model is appropriate for linking KT to TT as they relate to generating AT outcomes and impacts. Manufacturers and practitioners or clinicians are the primary audience for the transfer of technology-based products and services. KT is a process for introducing the core value--the innovation--into the context of the target audience's own value systems. The need to translate knowledge from one value system to another may happen between sectors. NIDRR, for example, expects manufacturers to transform research findings into new products, or it expects practitioners and clinicians to agree to use, or recommend, a particular product or service.

As noted above in CIHR's KT model, the application of contextualized knowledge to generate outcomes is intended to result in beneficial impacts on target populations. Getting from knowledge to impact requires decisions, resources and action, ideally in partnership with target-audience representatives. The Knowledge to Action model imparts the focus on action and is highly relevant to AT where the standard industry practices of TT and new product (or service) development and delivery must be applied to generate the desired impacts for intended beneficiaries.

The Knowledge to Action (KTA) Model

The premise of the KTA model is that KT deals with three inter-related issues: (a) making users aware of knowledge and facilitating their use of it, (b) closing the gap between what we know and what we do, (c) moving knowledge into action.

The KTA model (see Figure 5) depicts these issues as three components of knowledge creation (funnel) and knowledge application (cycle) systems (Graham et al., 2006; Graham & Tetroe, 2007).

Integrated KT Versus End-of-Grant KT

KT can be initiated anywhere along the research continuum. Initiating KT at the earliest stages of idea inception is called *integrated KT*. Initiating KT after research outputs are generated is called *end-of-grant KT*. The KTA model is applicable under either the *integrated KT* or the *end-of-grant KT* situations. Because KT is relatively new to the U.S., domestic researchers are not expected to have applied KT at the inception of their projects. Thus the discussion here will focus on the end-of-grant perspective.

KT is a process for considering the needs and values of knowledge users. The research knowledge can be tailored at the end-of-grant

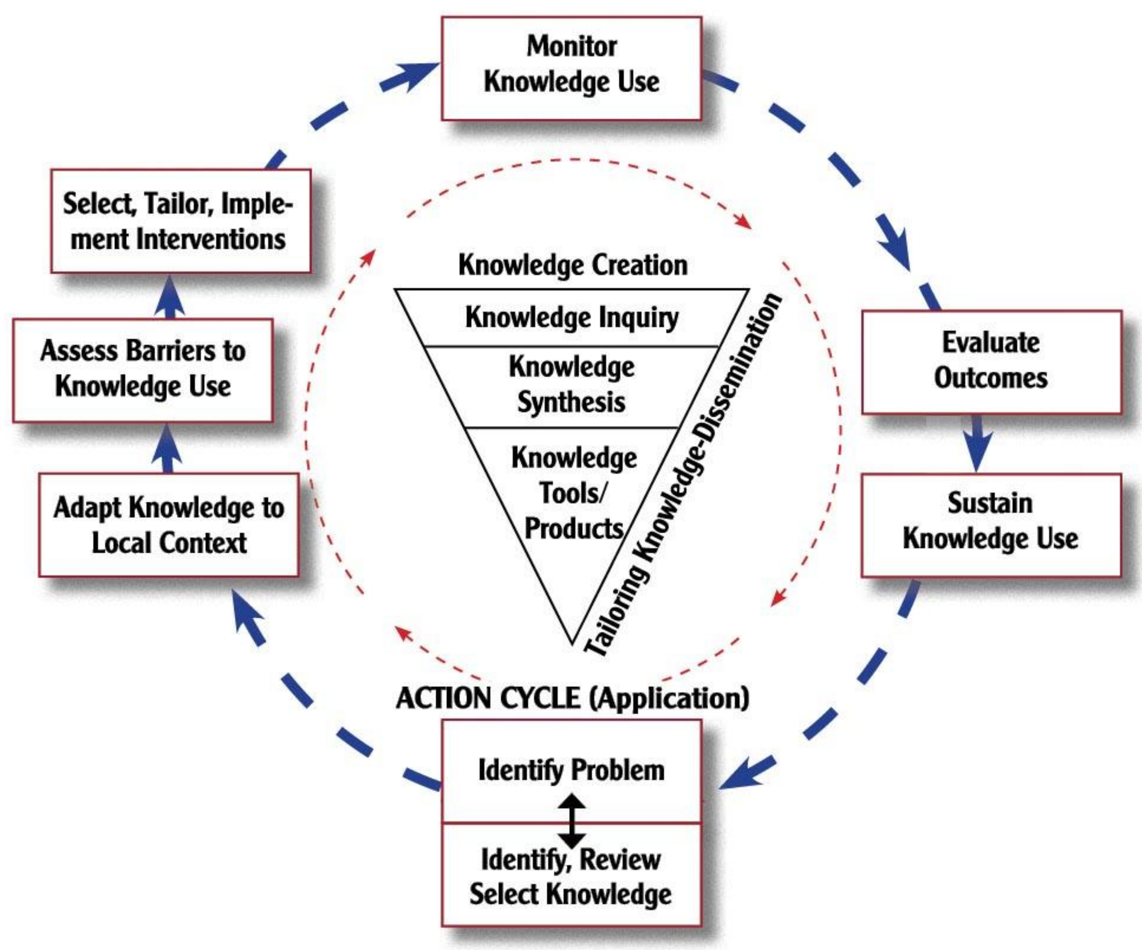

Figure 5. Knowledge to action model.

stage for optimal communication with those knowledge users. Better yet, knowledge users' needs and values can be built directly into the research design at the conception of the new project. The parallels between the KT and TT processes are readily observable. In terms of model, method and likelihood of success, supply-push technology transfer is equivalent to end-of-grant knowledge translation, while demand-pull TT is equivalent to beginning-of-grant KT. The general rule holds that incorporating the needs and values of the intended users at the beginning is much more efficient and effective than engaging them after completing the work.

Recent syntheses of KT literature indicate that new interventions should implement multi-method strategies, including passive dissemination and training as well as active demonstration and technical assistance to include (Kitson & Bisby, 2008; Sudsawad, 2007): (a) diffusion--researcher-push and collaborative tailoring (researcher push; user pull); (b) conference presentations and peer-reviewed publications (open-access policy); (c) non-peer-reviewed publications; (d) Web site postings; (e) end-of-grant report to funders and summary briefings to stakeholders; (f) educational sessions with patients, practitioners and or policy makers; (g) engaging end users in developing and executing dissemination or implementation plan; (h) commercialization efforts; tools creation; and (i) media engagement; use of knowledge brokers.

Reconciling Concepts/Definitions for KT and TT

Key concepts and definitions found in the literature focus on the verbs (e.g., translate, transfer, disseminate, diffuse, implement, utilize), rather than the nouns (e.g., knowledge, innovation). That is, the focus is on the transaction rather than on the object. In KT, the object is the knowledge product generated by the research activity, whether in conceptual or tangible form. In KT for TT, the knowledge product can be either conceptual or tangible at the knowledge producer's output stage. But it becomes tangible within a product or service at the knowledge user's outcome stage. The tangible product or service creates a beneficial impact within the target population. Given the transition from conceptual to tangible form, the utility, or value, of the knowledge object within the context of the intended beneficiaries becomes a critical success factor for achieving eventual impacts.

Knowledge as Innovation

The KT literature contains little mention of the inherent value of the knowledge object itself. Value is comprised of both internal rigor (merit) and external relevance (worth). Few explicit definitions of the innovation exist. It appears that most attention focuses on the functional attributes of the knowledge rather than the inherent value of the knowledge. Two definitions are

> "An idea, practice or object that is perceived as new by an individual. . .If the idea seems new to the individual, it is an innovation" (Rogers, 1995, p. 11).

> ". . .A novel set of behaviors, routines and ways of working that are directed at improving. . ." (Greenhalgh, Robert, MacFarlane, Bate, & Kyriakidou, 2004, p. 582).

Greenhalgh et al. (2004) note that assuming the inherent value of a knowledge object under study is both a convenience and a dilemma. It is a convenience in that it permits KT models to hold constant the 'innovation value,' and it allows studies to focus on the transactional attributes of the knowledge, such as: (a) *How* the knowledge object's value might be perceived by potential users depending on their motivations for utilization (e.g., instrumental, conceptual, symbolic; Lavis, Robertson, Woodside, McLeod, & Abelson, 2003); (b) *Which* attributes of the knowledge object offer value within the user's context (e.g., relative advantage; Meyers, Sivakumar, & Nakata, 1999), compatibility (Foy, MacLennan, Grimshaw, Penny, Campbell, & Grol, 2002), complexity and face validity (Denis, Hebert, Langley, Lozeau, & Trottier, 2002), and trial use and task issues (Yetton, Sharma, & Southon, 1999); (c) *Which* user attributes might influence their ability to perceive, adapt and apply the value of the knowledge object (e.g., education, motivation, structure; Savory, 2006); and (d) *Which* levels of the organization are involved in making decisions about use of the knowledge object (e.g., individual, organization, sector, system).

However, the assumption of inherent value of a knowledge object is also a dilemma because without any standard criteria for 'innovativeness,' one cannot reliably attribute variance in transaction outcomes to the many other explanatory factors proposed. Some authors hint at this dilemma. They suggest that successful diffusion requires extra attention to the validity and reliability of the knowledge output, because this inherent value to others is the core building block upon which KT efforts will be constructed (Carlisle, 2004).

Indeed, the assumption that scientific research findings in the context of practice are naturally innovative has not been tested: "To use Rogers' model in health requires us to assume that the innovation in classic diffusion theory is equivalent to scientific research finding in the context of practice, an assumption that has not been rigorously tested" (Estabrooks et al., 2006, p. 29).

The field of KT could resolve this dilemma by adopting an existing, well-established convention for determining a knowledge output's innovativeness. The U.S. Patent and Trademark Office (USPTO) has a clear definition. Based on three criteria (listed here and defined below), it serves as the basis for granting an individual's claim of innovative knowledge: (a) novelty, (b) non-obviousness, and (c) utility (Ohio State University, Office of Research, n.d.).

The patent system recognizes that the three criteria may be assessed subjectively or objectively. A knowledge creator may subjectively believe that all three criteria are met. The patent application process provides an opportunity for an objective review of these criteria. The process revolves around the concept of a claim, the articulation of what an individual believes he or she is adding to the knowledge base. In a patent application, the claim is written in the first person singular: "I claim the following . . ."

The individual's claims are then reviewed objectively within the USPTO system.

The *novelty* criterion is the most straightforward in the patent system. It is based on a search of key words and related terms in prior patent claims.

Non-obviousness criteria considers one's ability to make the claim based on familiarity with the existing knowledge base–the prior art. This is important for determining ownership over the innovation, but it is not relevant to the potential users.

Utility criteria involve an extrapolation from claims of novelty to the application of the same claims in practice. The utility criteria include the feasibility of making the innovation work in reality (the basis for rejecting many claims of innovation in the categories of alchemy and perpetual motion machines).

By adopting a modified standard for innovativeness, every KT study could begin by stating the inherent value of the knowledge claim: *What knowledge is claimed and on what basis is it determined to be novel, feasible and useful?* The presence of actual innovativeness is critical to validating any KT model. If an attempt to diffuse knowledge fails, is the failure attributable to the diffusion process or the utility and value of the knowledge itself? Were users correct to reject the knowledge, or were they incapable of adapting useful knowledge to their own circumstances? Verifying the presence of innovation helps clarify such interpretations.

Here is an example of why innovation requires a standard definition. In the above summary of diffusion of innovation research, innovation was defined subjectively. In 1995, Dr. Rogers wrote that one Iowa farmer was classified pejoratively as a 'laggard' for rejecting all forms of chemicals (e.g., weed control, fertilizers, insecticide, feeds), which were perceived as innovations. The laggards say chemicals harm songbirds, earthworms, and other aspects of the natural environment.

Dr. Rogers said, "I have come to understand that the organic farmer respondent in Iowa may actually have been the most innovative individual in my study" (Rogers, 1995, p. 425). A standard definition of *innovation* may have included this farmer's concerns in the criteria and perhaps changed the study's conclusions.

Under the *integrated* KT approach, participants in the KTA model would first identify a problem then search for knowledge to address the problem. In the case of integrated KT, the knowledge would be critically appraised to determine its validity and usefulness for a particular problem (Graham et al., 2006). Under the end-of-grant KT approach, KTA participants cannot identify a specific problem a priori. Instead, the participants must consider the validity and utility of the new knowledge for as many potential applications as possible at the three levels of use and across the six user categories. Participants must assess the inherent value of each new scholarly knowledge object in the context of future applications by knowledge users. For example, the form of a knowledge object can be depicted in a series of stages with value and utility to users increasing along a value chain (object, data, information, knowledge, wisdom; McInerney & Day, 2007).

To the extent that KT literature has considered the inherent value of knowledge objects, the definitions have encompassed both subjective and objective perspectives on innovation value. Here is a four-point scale for assessing innovations:

- *Grade A Innovations*–Subjective (looks new or useful) and objective (is new or useful)
- *Grade B Innovations*–Subjective but not objective--false positive
- *Grade C Innovations*–Not subjective but is objective--false negative
- *Grade F Innovations*–Not subjective or objective

Grade A innovations will be defined as representing true value within a knowledge output. Grade A innovations demonstrate all three applicant criteria: novelty, feasibility and utility.

Grade B innovations may be fairly common among research outputs given that a peer review may focus on the originality of the research design or the gap addressed in the literature. Being novel does not always imply being useful to others. Most 'garage inventions' are Grade B. The inventor as creator subjectively bestows utility and value on something, which, objectively, has none.

Attempts to diffuse Grade B innovations will prove fruitless as the absence of utility is exposed. However, because of their appearance of value, Grade B innovations may be even more wasteful than Grade F innovations.

Grade F innovations are not innovative in any way. Few waste time and effort on diffusing them. It bears noting that integrated knowledge translation would have given researchers information that led to abandonment of the work at an early stage.

Grade C innovations can be mistaken for something that is already known--called competency traps (Martins & Kambi, 1999). Grade C innovations are worth diffusing because if the subjective barriers are overcome, the innovation will deliver utility and value to the users.

Studies of the effectiveness of KT for diffusion, uptake and use should control for the quality of the subject 'innovation.' Of course, a lack of sensitivity within this preliminary four-point scale is limiting. Theoretically, the minimum threshold for a Grade A score is value for any of the six user categories, at any of the three organizational levels, in any of the three forms of use. Some knowledge outputs may achieve the minimal threshold while others may represent utility and value across multiple categories of users, at multiple levels and in multiple forms. Clarifying these variables and establishing valid metrics for innovations will be an important area of research.

Types of Knowledge Use

As mentioned above, any assessment of knowledge value has to consider all three ways in which users might apply knowledge, as each represents a different perspective on the knowledge value. The literature recognizes three types of knowledge utilization: *instrumental*, *conceptual*, and *symbolic* (Huberman, 1994): (a) *instrumental* utilization is the direct application of research, typically in a tangible and material form, such as a clinical protocol, measurement instrument, or device; (b) *conceptual* utilization changes awareness, perspective or conceptualization but does not result in direct, tangible action; and (c) *symbolic* utilization applies research in support of a previously established position or to accomplish a desired outcome. There is no direct application nor is there any lasting impact on the user. The research findings are a means to an end.

One author created a scale to measure the three levels of utilization and found that a complex activity, operating at all three levels, can be measured with relatively simple questions (Estabrooks, 1999). Studies of knowledge use should take into account these variables within the parameters of the six categories of potential users.

KT Capabilities of User Organizations

With value (innovativeness) of new knowledge outputs from the *knowledge production system* established, attention turns to establishing the capabilities of the *knowledge value system* to uptake and use of these innovations. Literature describes technology-related KT capabilities of user categories at the organization level as being comprised of five components (Savory, 2006):

1. *Absorptive capability*--The organization's technological capability depends on its ability to recognize, assimilate and apply knowledge from outside the organization (Cohen & Levinthal, 1990). A prerequisite is a prior path of learning in the relevant domain. Scientific research is the relevant domain of most NIDRR grantees; few have a prior learning path in the product development domain. The applicant's utilization program will help close the gap in prior learning.

2. *Combinative capability*--Once absorbed, new knowledge must be integrated and reconfigured with the existing knowledge base in novel ways (Kogut & Zander, 1992). The absorbed knowledge must be codified in a new context before it can be applied. This codification process is similar to linguistic translation and involves abstracting the original knowledge, codifying it in the new context and diffusing the original knowledge even beyond the original context (Boisot, 1998).
3. *Transformational capability*--The ability to transform conceptual knowledge into a tangible product that meets a valid need. This ability requires an organization to learn at three different levels or loops (Boisot, 1998; Leonard, 1995): (a) single-loop learning represents an organization's core competence; (b) double-loop learning coordinates and uses a combination of resources; and (c) triple-loop learning is the ability to adapt to changing circumstances; it is the process of learning to learn.
4. *Dynamic capability*--The prior three capabilities describe characteristics of knowledge use within a static context: how it imports and implements external knowledge then integrates that knowledge--through experimentation and prototyping--to solve technological problems. Dynamic capability represents the organization's ability to hold the knowledge application on course while the contextual environment is in a state of flux (Leonard, 1995).
5. *Innovation capability*--The presence of all of these other capabilities collectively constitute an organization's ability to survive by generating novel, feasible and useful products and services for its customer base. Such innovation requires a direct and continuous

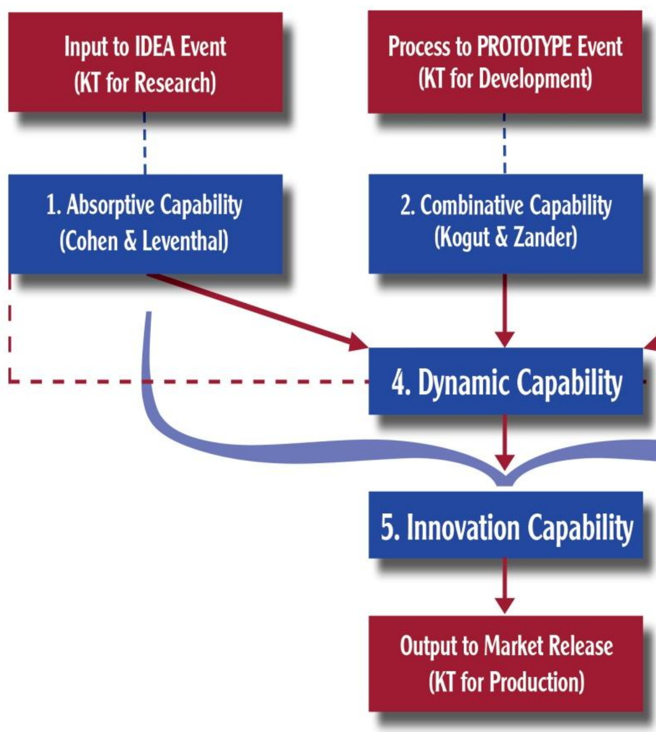

Figure 6. The role of organizational KT capabilities in advancing TT.

Table 1
Create Awareness or Facilitate Use

Attributes to Create Awareness	Attributes to Facilitate Use
The source or originator of message	Influential person as the prime source, reinforced by messages about value of change from multiple internal and external channels.
Channel used to communicate message	Personalized interaction as the channel, with message presented in user-friendly formats, language and style, and repeated over time.
The content of the message	Message grounded in local experience and setting to show it is feasible, adaptable for trial.
Characteristics of the audience	Opinion leader as the initial audience and candidate for early adoption, representing the local need to consider the change.
The setting where the message is received	Local, informal settings where users can test concept and weigh risk to incentives and risk of disincentives.

interplay of KT between knowledge producers and users, and of TT between product producers and consumers.

Figure 6 shows how the five organizational competencies developed through KT practices contribute to an organization's ability to move ideas into tangible product or service forms.

Facilitating Knowledge Use Through KT

The espoused contribution of KT is to facilitate the use of research-based knowledge by target audiences. Sponsored programs may generate innovative outputs, identify target audiences, anticipate various forms of use and even deliver the knowledge through multiple approaches. All are necessary but collectively they are insufficient to make use happen.

Several authors addressed the facilitation of knowledge use in ways that informed the applicant's strategic model and tactical methods. This literature is summarized here then referenced within each aspect of the research, development and utilization project.

One perspective relevant to facilitating knowledge use asserts that diffusion, dissemination and implementation are related phases. They form a process of increasingly active communication reflecting more focused intent. Each subsequent phase depends on the success of its predecessor (Lomas, 1993). Knowledge producers who shift from diffusion to dissemination have changed their intent toward communication outcomes, reflected in changed behavior from passive to active.

However, evidence shows that this shift on the part of the producer is insufficient to prompt knowledge users to shift their intent and behavior from passive awareness of the knowledge to its active use. The successful transmission of knowledge from producer to potential user can only pre-dispose the user to change behavior by raising awareness about the opportunity to change. Even tailored dissemination only predisposes and is not sufficient to prompt action (Green & Eriksen, 1988).

The RERC on Technology Transfer has verified these findings through repeated examples. Decisions and actions to apply (implement) knowledge come from the attitudes and behaviors of the user. No matter whether one leads a horse to water, as the saying goes, a lack of follow-through by users is a reminder that one can't necessarily make the horse drink.

What triggers action to implement an innovation from the user's perspective? The field of marketing has long focused on tools and techniques to prompt action by targeted consumers. Literature on persuasive communication distinguishes between a set of five general attributes that influence any audience's awareness of new knowledge (Table 1 left side), and a set of five specific attributes that contribute to shifting user intent--prompting action (Table 1 right side; Lomas, 1993; Winkler, Lohr, & Brook, 1985).

A second concept relevant to facilitating knowledge use is *knowledge boundaries*. Knowledge boundaries lie at the point of intersection between the flow of knowledge to users, and the reception of knowledge by users (Carlisle, 2004). Knowledge boundaries exist in three progressively complex types, representing three increasingly complex processes. Moves toward greater complexity still require the less complex capacities (see Table 2).

KTA Model – Knowledge Creation Funnel and Application Action Cycle

The prior discussion of the KTA model focused on the new innovation outputs generated by the knowledge production system. Now attention turns to outcomes and impacts that require action on the part of the Knowledge User System (KUS). Achieving these outcomes and impacts through knowledge utilization by the KUS requires an operational version of the KTA model.

Table 3 shows how the steps in the KTA Knowledge Creation Funnel and Action Cycles (column 1) intersect with key concepts from the KT and TT literature (column 2). These key concepts from KT and TT still

Table 2
Knowledge Boundary Type and Process

Knowledge Boundary Type	Knowledge Boundary Process
Syntactic – Information processing model with a common lexicon to cross the boundary.	*Transfer* – The common lexicon requires stable conditions and is destabilized by novel information.
Semantic – Community-of-practice model where novel information is reconciled through shared meanings or shared mechanisms.	*Translation* – Interpretation required to maintain effective communication. Revealed barriers require carriers.
Pragmatic – Creative abrasion model where novelty generates competing interests that must be resolved via negotiation.	*Transformation* – Create new knowledge by integrating existing knowledge *at stake* along with the value of the innovation.

Table 3
Integrating KT and TT to Facilitate Knowledge Utilization

KTA Knowledge Creation Funnel	*Key KT Concepts*	*Required Integration of KT & TT in Operational Terms*	*Strategies to Facilitate Utilization*
Identify stakeholders and establish shared understanding of KT process.	Knowledge Production System and Knowledge Utilization System; KT & TT models.	Synthesize KT knowledge within KTA model; then reconcile with TT model, methods and measures.	Source of message – send expert message through professional organization.
KTA Steps in Action Cycle	*Key KT Concepts*	*Required Integration of KT & TT in Operational Terms*	*Strategies to Facilitate Utilization*
1) Identify knowledge need (integrated KT) or validate knowledge value (end-of-grant KT).	Research-based knowledge outputs. New knowledge = innovation?	Validate Grade A innovations from technology-related research projects.	Content of the message – true innovation with value to members.
2) Placing useful knowledge in specific context of problem.	Knowledge diffusion, transfer, utilization; five organizational capabilities for use.	Profile value systems of targeted knowledge user categories.	Audience characteristics – opinion leader via organization.
3) Assess barriers and identify carriers to overcome them.	Three levels – individual, organization and sector; transactional attributes of user and knowledge.	Identify specific barriers and carriers for innovations in context of targeted users in each category.	Opinion leader; local setting and norms; feasible, flexible, testable.
4) Tailor intervention to known barriers and target audiences.	Diffusion, syntactic, transfer. Dissemination, semantic, translation. Implementation, pragmatic, transformation.	Create communication vehicles tailored to each target audience for delivery through multiple modes.	Channel used – user-friendly message delivered via multiple channels over extended time.
5) Monitor and measure knowledge utilization	Three types of knowledge use – instrumental, conceptual and strategic.	Pre- and post-tests of users; and or secondary source evidence of utilization.	Recognize need for change, value knowledge as change agent.
6) Determine the impact of use and assess costs involved.	Cost-benefit to KPS and to KUS, as well as value to targeted beneficiaries.	Calculate cost of KT intervention and benefits of outcomes and impacts.	Mid-Term: Collect quantitative and qualitative evidence of value.
7) Sustaining knowledge use: Recapitulates steps 4-7.	New area of KT interest: Literature on public policy and systems change.	Use cost-benefit results to promote movement from end-of-grant KT to integrated KT.	Long-Term: Generate more evidence of value; promote KT change to KPS system.

require additional integration (column 3) before they can be applied in operational terms to facilitate knowledge use (column 4). To facilitate use, the operational model cannot stop with the Knowledge Creation Funnel. Instead, the KTA's Steps in the Action Cycle must also be expressed in operational terms applied by the knowledge users. The established models, methods and measures of technology transfer offer such operational terms.

Table 3 can also be taken to consider the relationships between existing theories (column 2), existing models (column 1), and new methods (column 3), and how they all might converge to facilitate the desired outcome of knowledge utilization by target audiences (column 4). From this perspective, columns 1, 2, and 4 refer to the current SOS. Column 3 represents the emerging research agenda in relation to integrating TT with KT.

For example, the third column in Table 3 suggests that integrating KT and TT in operational terms was important in creating an operational KT model. One approach would be to create a parallel linear model from the circular Knowledge to Action model, which could be based on the PDMA's linear TT model involving these 20 steps. Such a linear model should consider the dynamic aspects of the KTA model. However, the linearity would permit model builders to identify analogous activities along the KTA and PDMA models. These analogous activities may occur at different points in the progression through the respective models, but the established TT tools and products for conducting the activity may be readily converted into tools and products to conduct the KT activity.

Exploring the TT stages in greater detail would help determine the viability of such a crosswalk from TT to KT models. Within the CIHR KT model (Figure 3), the KT_5 decision point initiates the application of knowledge in a tangible form, through the 20-step development process where research discoveries transform into product outcomes. Development activity occurring between the creation of new knowledge and its release as a product in the marketplace involves two phases, *prototype development* and *product development*.

1. *Prototype development*--In business terms, this phase involves a reduction to practice. Prototype development determines the invention's feasibility in the form of the envisioned product. The process consumes the first 10 steps in Figure 2, culminating in a final prototype (Bowling Green State University, 1997).
2. *Product development*--The prototype can only become a product if a manufacturer decides to invest the necessary resources to transform the prototype into a set of designs and specifications representing a new product. The product development phase consumes the second 10 steps in Figure 2, culminating in the first unit of a produced product.

The decision to actually manufacture and release a new product into the marketplace involves an entirely different and additional cycle of activities and practices called *production*, as indicated in Figure 2. This production cycle occurs beyond the *product* event so its details fall outside the scope of the initial KT and TT model crosswalk. It is important to note that the innovation process continues after the product reaches the marketplace because actual use drives continued product innovation (Howells, 2004). For example, product users identify gaps or misconceptions in the original expectations for product use. The process of use also identifies novel applications for the technology. So, long-term efforts to build parallel models would eventually also have to address analogies in the production cycle as well.

Subsequent to the product's market release, acquisition and use by targeted beneficiaries generates impacts on individuals, their communities and on society. These impacts lead discussion back to the CIHR KT model (Figure 3) where the *impacts* oval in the bottom left represents these consequences from acquisition and use. The *impact* stage precipitates the final KT opportunity: KT_6--influencing subsequent rounds of research based on the impacts of knowledge use.

At that point, the cycle of research, development and production may repeat (see Figure 4, RDP model). This is the dynamic nature of technology-related innovations. Having an operational KT model for research, linked to the existing operational TT model for development and production, would provide a meta-model for technology-related innovations. There is precedent for such a meta-model, most notably in times of national crisis such as World War II and the Space Race. In such instances, government united academia and industry to create innovative technologies through research. These technologies translated into tangible products in response to clearly defined national needs.

Implementing KT Processes to Accomplish TT Outcomes

The KT process is designed to communicate the value of conceptual knowledge, while the TT process is designed to transform this value into tangible outcomes. The AT field needs to link both processes to increase the outcome yields from technology grantees as demonstrated by new or improved products in the marketplace.

The frameworks for KT and for TT discussed up to this point can now all be linked to illustrate the full transformation of knowledge from the idea for the application of knowledge in the mind of the researcher, through to the impact of new product outcomes on the intended beneficiaries. The initial research discovery sparks an idea for an application. That idea then becomes a tangible proof-of-concept prototype via Phase I development activity (Steps 1-10), and is then refined into a product under Phase II development activity (Steps 11-20). The resulting product is released into the marketplace where it benefits the target users. These target beneficiaries then generate quality of life, economic, and social impacts.

This entire process between the initial *idea* input and eventual impacts from the *product* outcome is represented by Figure 7. From left to right, Figure 7 begins with the *KT Application of Knowledge*, which corresponds to the first white oval on the bottom of the CIHR KT model in Figure 1, where some action follows the decision to apply the new knowledge in a tangible form--the *idea* event.

Figure 7 proceeds through the 20 steps of

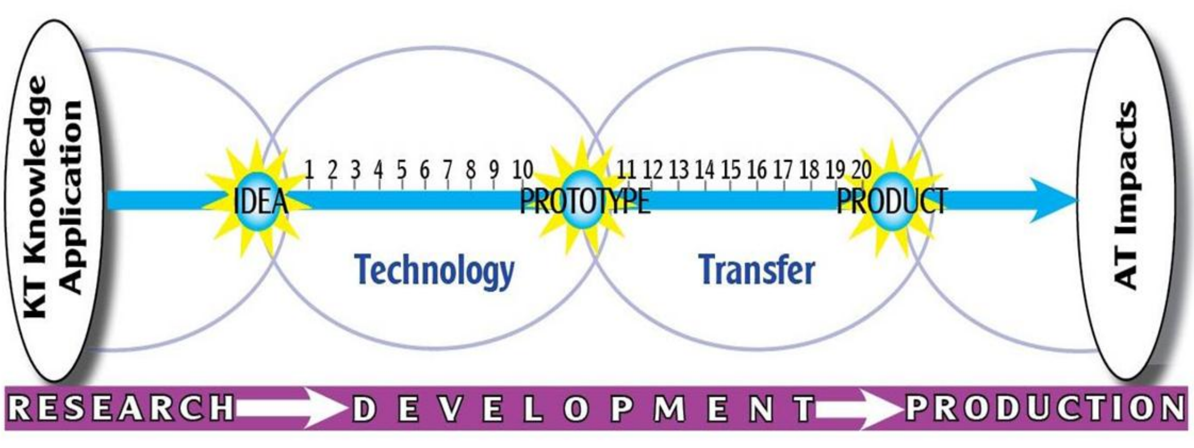

Figure 7. From KT input to TT impacts.

product development. The first 10 steps to *prototype* event are typically performed by NIDRR technology grantees. Some grantees--a few RERC entrepreneurs and many SBIR enterprises--continue with steps 11 through 20. This moves them away from corporate partnerships and toward becoming manufacturers themselves. In other instances, grantees stop internal work at the prototype event and create formal partnerships with corporate manufacturers to achieve the product event.

Figure 7 shows the product event, which is followed by all the commercialization activity. The far right side concludes with the second white oval labeled as *AT Impacts*, which corresponds to second white oval at the bottom left in the Figure 1 CIHR KT model, where impacts result from the application of knowledge. Figure 7 is a reference diagram for SOS discussion regarding the transformation of knowledge outputs into product outcomes.

The SOS Q&A for 2008-2013

The SOS progresses with knowledge drawn from research and from practice. The four questions from 2003 are revisited here with a view toward the next steps in progress.

1. What steps are necessary for technology transfer to evolve from a professional practice to an academic discipline?

The evolution from practice to discipline will be advanced by linking the theory and practice of KT to the models, methods and metrics of TT. This addresses concerns about the ad hoc nature of the process and generates needed understanding of how and why transfers occur between knowledge producers and knowledge users. The government and public demand that research contributes to societal needs is precisely the impetus to move from art to science. KT arose from a complex mix of forces to contribute to the management of technology innovations. Indeed, the prior discussion illustrated the interdependence between processes, previously treated as the purview of independent sectors.

2. The T^2RERC is operationalizing the elements of TT within a valid and reliable process model. What next steps are required to advance the field of TT?

With an operational TT process established, the next step is to crosswalk its components to create an operational model of knowledge translation. Then, applying the operational KT model in practice for the field of AT will establish its validity along with its potential for application in other fields of practice. Combining existing evidence from research with new evidence from application will generate a more formal process, and establish the approaches considered to represent best practices.

3. How can the T^2RERC's activity further promote mainstream science and technology interest in the field of AT?

Active efforts to engage stakeholders in the translation of knowledge about technology-related needs in the field of AT, and about the potential utility of AT knowledge for application in other fields, is a core activity of the KT for TT approaches to increased outcomes and impacts. Integrated KT involves an articulation of benefits for both the knowledge producer and the knowledge user, including both professional and personal incentives for collaboration across fields of application and economic sectors.

4. How can the T^2RERC's technology transfer models be implemented to facilitate TT in other industries?

KT represents the scholarly entrepreneurialism of the academic sector, while TT represents the monetary entrepreneurialism of the industrial sector.

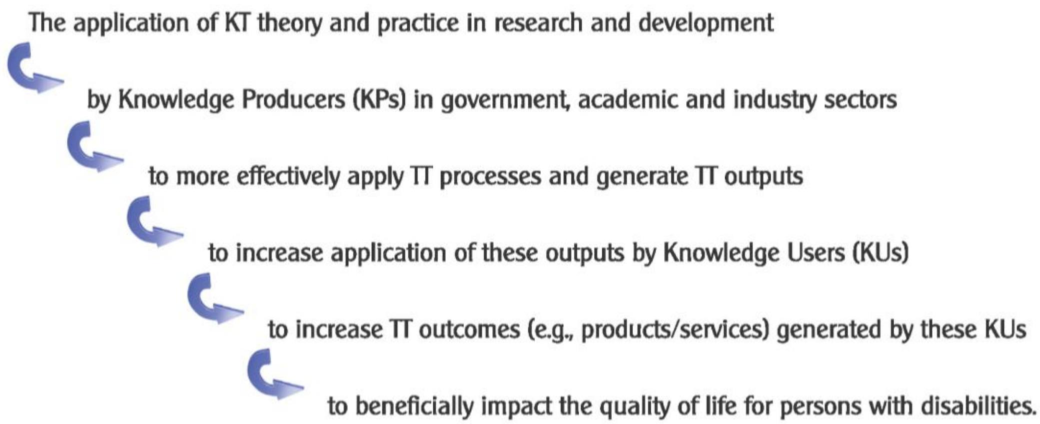

*Figure 8.*The Knowledge Translation for Technology Transfer Cascade.

The convergence of these two processes will improve researchers' abilities to see and plan for the downstream applications of their knowledge outputs. At the same time, it will improve the manufacturers' abilities to identify and evaluate the potential contributions of new knowledge to gaps in their product and service offerings. Testing the KT for TT model through intervention studies will provide the cost-benefit analysis necessary to make sound decisions regarding the future application of this model by the government, academic and business sectors.

In summary, *KT* for *TT* can be abbreviated as shown in Figure 8.

The field of AT can advance if KT strategies are used to communicate this model to knowledge producers and if KT strategies are used to communicate their innovative knowledge outputs to knowledge users. The integration of KT and TT models--and the broader integration of research, development and production activities--is the next critical contribution to the state of the science, the state of the practice and the state of the art.

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References

Agency for Healthcare Research and Quality. (2001). *Translating research into practice (TRIP)* – II. Retrieved June 26, 2008, from http://www.ahrq.gov/research/trip2fac.htm

Americans with Disabilities Act, 42 U. S. C. §§12101 *et seq*. (1990).

Bauer, S.M. (2003). Demand pull technology transfer applied to the field of assistive technology. *Journal of Technology Transfer, 28,* 285-303.

Belkhodja, O., Amara, N., Landry, R., & Ouimet, M. (2007). The extent and organizational determinants of research utilization in Canadian health services organizations. *Science Communication, 28*, 377-417.

Belliveau, P., Griffin, A., & Somermeyer, S. (Eds.). (2007). *The PDMA toolbook III for new product development*. New York: John Wiley & Sons.

Boisot, M. H. (1998). *Knowledge assets: securing competitive advantage in the information economy.* Oxford, England: Oxford University Press.

Bos, V., & Van Kammen, J. (2007). *Knowledge synthesis: A guide*. The Hague and Woerden: Zon Mw and NIGZ.

Bowling Green State University. (1997). *Prototyping: Characteristics of a prototype*. Retrieved February 18, 2008, from http://csweb.cs.bgsu.edu/maner/domains/Proto.htm#3

Brandt, E. N., & Pope, A. M. (Eds.) (1997). *Enabling America: Assessing the role of rehabilitation science and engineering.* Washington, DC: National Academy Press.

Bransomb, L. M., & Keller, J. (1998). *Investing in innovation: Creating a research and innovation policy that works.* Cambridge: MIT Press.

Bzdel, L., Wither, C., & Graham, P. (2004). *Knowledge utilization resource guide*. Retrieved October 15, 2009, from http://www.uofaweb.ualberta.ca/kusp/pdfs/KUResourceGuide.pdf

Canadian Health Services Research Foundation. (2000). *Health services research and evidence-based decision making*. Retrieved June 24, 2008, from http://www.chsrf.ca/knowledge_transfer/pdf/EBDM_e.pdf

Canadian Institutes of Health Research Act. (2000). *Bill C-13, Chapter 6*. Retrieved March 13, 2008, from http://www2.parl.gc.ca/HousePublications/Publication.aspx?pub=bill&doc=C13&parl=36&ses=2&File=28&Language=E

Canadian Institutes of Health Research. (2008). *Knowledge transfer and commercialization*. Retrieved February 22, 2008, from http://www.cihr-irsc.gc.ca/e/29529.html

Canadian Institutes of Health Research. (n.d.). *About knowledge translation: The KT portfolio at CIHR*. Retrieved July 3, 2008, from http://www2.parl.gc.ca/HousePublications/Publication.aspx?pub=bill&doc=C13&parl=36&ses=2&File=28&Language=E

Carlisle, P. R. (2004). Transferring, translating and transforming: An integrative boundary framework for managing knowledge across boundaries. *Organization Science, 15*, 555-568.

Carnegie Mellon, the Robotics Institute. (n.d.). *Quality of Life Technology Center.* http://www.ri.cmu.edu/research_project_detail.html?project_id=583&menu_id=261

Center for an Accessible Society. (1998). *About the National Institute on Disability and Rehabilitation Research*. Retrieved September 30, 2009, from http://www.accessiblesociety.org/nidrr.htm

Christensen, C. M., (2003). *The innovator's dilemma: The revolutionary book that will change the way you do business.* New York: Harper Collins.

Cohen, W., & Levinthal, D. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly, 35*(1), 128-53.

Covey, S. R. (2004). *The 7 habits of highly effective people*. New York: Free Press.

Dalton, C. C., & Gottlieb, L. N. (2003). The concept of readiness to change. *Journal of Advanced Nursing, 42*, 108-117.

Denis, J. L., & Lomas, J. (2003). Convergent evolution: The academic and policy roots of collaborative research. *Journal of Health Services Research and Policy, 8* (Suppl. 2), S1-S6.

Denis, J. L., Hebert, Y., Langley, A., Lozeau, D., & Trottier, L. H. (2002). Explaining diffusion patterns for complex health care innovations. *Health Care Management Review, 27*(3), 60-73.

Dunn, W. N. (1983). Measuring knowledge use. *Science Communications, 5*, 120-133.

Education for All Handicapped Children Act, 20 U.S.C. §§ 1400 *et seq*. (1975)

Empowering Through the New Freedom Initiative. (2001). Retrieved October 1, 2009, from http://georgewbush-whitehouse.archives.gov/infocus/newfreedom/

Estabrooks, C. A. (1999). The conceptual structure of research utilization. *Research in Nursing and Health, 22*, 203-216.

Estabrooks, C. A., Thompson, D. S., Lovely, J. J., & Hofmeyer, A. (2006). A guide to knowledge translation theory. *Journal of Continuing Education in the Health Professions, 26*, 25-36.

Foy, R., MacLennan, G., Grimshaw, J., Penny, G., Campbell, M., & Grol, R. (2002). Attributes of clinical recommendations that influence change in practice following audit and feedback. *Journal of Clinical Epidemiology, 55*, 717-722.

General Accounting Office. (1999). *Technology Transfer: Number and characteristics of inventions licensed by six federal agencies*. United States General Accounting Office, GAO/RCED-99-173f. Retrieved March 17, 2010, from http://ott.od.nih.gov/policy/rc99173.pdf

Giacomini, M. (2004). Interdisciplinarity in health services research: Dreams and nightmares, maladies, and remedies. *Journal of Health Services Research and Policy, 9*, 177-183.

Graham, I. D. (2007). Knowledge translation at CIHR. *Canadian Institutes of Health Research*. Retrieved July 3, 2008, from http://www.cihr-irsc.gc.ca/e/33747.html

Graham, I. D., & Tetroe, J. (2007). Whither knowledge translation: An international agenda. *Nursing Research, 56*(4), S86-88.

Graham, I. D., Logan, J., Harrison, M. B., Straus, S.E., Tetroe, J., Caswell, W., & Robinson, N. (2006). Lost in translation: Time for a map? *The Journal of Continuing Education in the Health Professions, 26*(1), 13-24.

Greenhalgh T., Robert, G., Macfarlane, F., Bate, P., Kyriakidou, O., & Peacock, R. (2005). Storylines of research in diffusion of innovations: a meta-narrative approach to systematic review. *Social Science & Medicine, 60*, 417-430.

Greenhalgh, T., Robert, G., MacFarlane, F., Bate, P., & Kyriakidou, O. (2004). Diffusion of Innovations in Service Organizations: Systematic review and recommendations. *The Milbank Quarterly, 82*, 581-629.

Grimshaw, J. M., Thomas, R. E., MacLennan, G., Fraser, C., Ramsay, C. R., Vale, L., et al. (2004). Effectiveness and efficiency of guideline dissemination and implementation strategies. *Health Technology Assessment, 8*(6). Retrieved March 17, 2010, from http://www.hta.ac.uk/fullmono/mon806.pdf

Grol, R., Wensing, M., & Eccles, M. (Eds.). (2005). *Improving patient care: The implementation of change in clinical practice*. Toronto, Ontario: Elsevier.

Hall, G. E., & Hord, S. M. (2006). *Implementing change: Patterns, principles, and potholes* (2nd ed.). Boston, MA: Allyn & Bacon.

Heinemann, A. W., Roth, E. J., Rychlik, K., Pe, K., King, C., & Clumpner, J. (2003). The impact of stroke practice guidelines on knowledge and practice patterns of acute care health professionals. *Journal of Evaluation in Clinical Practice, 9*, 203-212.

Hessels, L. K., & Van Lente, H. (2008). Re-thinking new knowledge production: A literature review and a research agenda, Research Policy*, 3,* 740-760.

Howells, J. (2004). *The management of innovation and technology: The shaping of the market economy*. London: Sage.

Jacobson, N. (2007). Social epistemology: Theory of the “fourth wave” of knowledge transfer and exchange search. *Science Communication, 29*, 116-127.

Kahn, K. B., Castellion, G., & Griffin, A. (Eds.). (2005). *The PDMA handbook of new product development: Second edition*. Hoboken: John Wiley & Sons.

Kitson, A., & Bisby, M. (2008). *Speeding up the spread putting KT research into practice and developing an integrated KT collaborative agenda*. The Alberta Heritage Foundation for Medical Research. Retrieved March 20, 2010, from www.ahfmr.ab.ca/download.php/fdb47de28f52562a0452b42534d33b39

Knorr-Cetina, K. (1999). *Epistemic cultures: How the sciences makes knowledge*. Cambridge, MA: Harvard University Press.

Kogut, B., & Zander, U. (1992). Knowledge of the firm, combinative capabilities, and the replication of technology. *Organization Science, 3*, 383-397.

Landry, R., Amara, N., & Lamari, M. (2001). Utilization of social science research knowledge in Canada. *Research Policy, 30*, 333-349.

Lane, J. P. (1999). Understanding technology transfer. *Assistive Technology, 11*(1), 5-19.

Lane, J. P. (2003). The state of the science in technology transfer: Applications for the field of assistive technology. *Technology Transfer Society, 28,* 333-354.

Lavis, J. N., Roberston, D., Woodside, J. M., McLeod, C. B., & Abelson, J. (2003). How can research organizations more effectively transfer research knowledge to decision makers? *The Milbank Quarterly, 81*, 221-248.

Leonard, D. (1995). *Wellsprings of knowledge: Building and sustaining the sources of innovation*. Boston: Harvard Business School Press.

Lomas, J. (1993). Diffusion, dissemination and implementation. Who should do what? *Annals of the New York Academy of Science, 703*, 226-235.

Lomas, J. (1993). Retailing research: Increasing the role of evidence in clinical services for childbirth. *The Milbank Quarterly, 71*, 439-475.

Mann, W. M., & Lane, J. (1995). *Assistive technology for persons with disabilities* (2nd ed.). City, ST: American Occupational Therapy Association.

Martins, L., & Kambi, A. (1999). Looking back and thinking ahead: Effects of prior success on manager's interpretation of new information technologies. *The Academy of Management Journal, 42*, 652-661.

McInerney, C. R., & Day, R. (Eds.). (2007). *Rethinking knowledge management: From knowledge objects to knowledge processes*. Berlin: Springer-Verlaag.

Medical Research Council. (2007). *Accelerating the translation of medical research*. Retrieved November 9, 2009, from http://www.mrc.ac.uk/Utilities/Documentrecord/index.htm?d=MRC003642

Meyers, P. W., Sivakumar, K., & Nakata, C. (1999). Implementation of industrial process innovations: Factors, effects and marketing implications. *Journal of Product Innovation Management, 16*, 295-311.

Miller, E. T., & Spilker, J. (2003). Readiness to change and brief education interventions: Successful strategies to reduce stroke risk. *Journal of Neuroscience Nursing, 34*, 215-222.

National Center for the Dissemination of Disability Research. (n.d.). About the National Center for the Dissemination of Disability Research (NCDDR). Retrieved June 28, 2008, from http://www.ncddr.org/about.html

National Institutes of Health, U.S. Department of Health and Human Services. (n.d.). *NIH roadmap for medical research*. Retrieved July 7, 2008, from http://nihroadmap.nih.gov/overview.asp

Nowotny, H., Scott, P., & Gibbons, M. (2001). *Re-thinking science knowledge and the public in an age of uncertainty*. Oxford, Cambridge, UK: Polity Press.

Nowotny, H., Scott, P., & Gibbons, M. (2003). Introduction: 'Mode 2' Revisited: The new production of knowledge. *Minerva, 41*, 179-194.

Ohio State University, Office of Research. (n.d.). *What are the criteria for obtaining a patent?* Retrieved June 27, 2008, from http://tlc.osu.edu/faqs/detail.cfm?faqID=49

Olmstead v. L.C., 527 U.S. 581, 138 F. 3d 893 (1999).

PHAE Group. (n.d.). *A typical product development journey "step-by-step."* Retrieved November 9, 2009, from www.phae.co.nz/pdj.htm

Phaneuf, M. R, Lomas, J., McCutcheon, C., Church, J., & Wilson, D. (2007). Square pegs in round holes: The relative importance of traditional and non-traditional scholarship in Canadian universities. *Science Communication, 28, 501-518.*

Prochaska, O., & D'Clemente, C. C. (1993). Stages and processes of self-change of smoking: Toward an integrative model of change. *Journal of Consulting and Clinical Psychology, 51*, 390-395.

Rehabilitation Act, 29 U.S.C. §§701 *et seq.* (1973).

Rehabilitation Act Amendments, 100 Stat. 1807 (1986).

Rehabilitation Act Amendments, 106 Stat. 4344 (1994).

Rehabilitation Act Amendments, 112 Stat. 1092 (1998).

Rogers, E. (1995). *Diffusion of innovations* (4th ed.). New York, NY: The Free Press.

Rosenbaum, M., Frankes, C. M., & Jaffe, Y. (Eds.). (1983). *Perspectives on behavior therapy in the eighties*. New York: Springer.

Rothwell, R. (1992). Successful industrial-innovation – critical factors for the 1990s. *R&D Management, 22*, 221-239.

Ryan, B., & Gross, N. C. (1943). The diffusion of hybrid seed corn in two Iowa communities. *Rural Sociology, 8*, 15-24.

Savory, C. (2006). Translating knowledge to build technical competence. *Management Decision, 44*, 1052-1076.

Sherwood, A. M., & Melia, R. P. (2007). Knowledge translation: A mandate for federal research agencies. *Journal of Rehabilitation Research and Development, 44*(3), vii – vix.

Sudsawad, P. (2007). *Knowledge translation: Introduction to models, strategies, and measures.* Austin, TX: Southwest Educational Development Laboratory, National Center for the Dissemination of Disability Research. Retrieved July 12, 2008, from http://www.ncddr.org/kt/products/ktintro/allinone.html

Technology-Related Assistance for Individuals with Disabilities Act, 29 U.S.C. §§ 2201 *et seq.* (1988).

Tetroe, J. (2008*). Knowledge translation at the Canadian Institutes for Health Research: A Primer.* (Focus Technical Brief 18). Retrieved June 6, 2008, from http://www.ncddr.org/kt/products/focus/focus18/

Tornatzky, L. G., Waugaman, P. G., & Gray, D. O. (2002). *Innovation U. New university roles in a knowledge economy*. Retrieved June 10, 2008, from http://www.southern.org/pubs/pubs_pdfs/iu_report.pdf

U.S. Department of Health and Human Services. (2007). *The contributions of behavioral and social sciences research to improving the health of the nation: A prospectus for the future* (p. 5). Retrieved July 2, 2008, from http://obssr.od.nih.gov/pdf/OBSSR_Prospectus.pdf

Weiss, C. H. (1979). The many meanings of research utilization. *Public Administration Review, 39*, 426-431.

Whyte, W. F. (Ed.). (1991). *Participatory action research*. Newbury Park, CA: Sage.

Yetton, P., Sharma, R., & Southon, G. (1999). Successful IS Innovation: The contingent contributions of innovation characteristics and implementation process. *Journal of Information Technology, 14*(1), 53-68.