Center on Knowledge Translation for Technology Transfer (KT4TT)

Project: Measuring reach and uptake of new knowledge from technology innovations.

Working Paper I: Need, context and concept

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Abstract

Background
A key challenge to implementation science is measuring the extent to which stakeholders are moving new knowledge from research and development activities into action. This process is characterized here as progressing from non-awareness to awareness, to interest and then to use -- either as intended or as modified by the stakeholder. Sponsors and grantees alike need a valid and reliable tool to measure changes in knowledge use over time, particularly for those projects involving technological innovations, which are increasingly expected to generate evidence of outcome and impact among target audiences. Such a tool would also permit comparative analyses between different strategies for communicating new knowledge to stakeholders. The Level Of Knowledge Use Survey (LOKUS) was created in response to these needs. This paper describes the tool's conceptual basis, while two companion papers respectively address tool development and psychometrics establishment.

Methods
A focused review of relevant literature sought appropriate measures of knowledge use or alternatively, fundamental concepts or frameworks useful for constructing such a measure. The search covered both individual studies relevant to knowledge use measurement and recent reviews of such studies. It was guided by the standards of merit and worth recommended in evaluation literature, reflecting the measure's psychometric soundness and practical utility to the instrument's users – sponsors and investigators of projects that generate new knowledge related to technology innovation.

Results
Several studies based on Roger's five stage model of innovation adoption appeared relevant and useful, the Level of Use (LoU) scale by Hall and colleagues coming closest to meeting the criteria. Its framework of levels and categories showed promise for in depth exploration of knowledge use by multiple stakeholders, although its qualitative operational model limited its feasibility for tracking outcomes from knowledge outputs.

Conclusions
The conclusion favoured the development of a new instrument systematically created through empirical validation in the technology innovation context, and initially guided by the LoU framework of levels and categories. The recommendation was also for a feasible format: a survey questionnaire eliciting self reported responses, and administered online to reach broad and diverse stakeholder audiences.

Background

This is first in a series of three papers that address the development of the Level of Knowledge Survey (LOKUS) instrument recently completed at the University at Buffalo's Knowledge Translation for Technology Transfer (KT4TT) Center. This paper describes the rationale and context of the instrument's development, leading to a conceptual basis for developing the instrument as a measure of knowledge use. Two sequel papers respectively address and describe the design and construction of the tool [1] and establishment of its psychometric properties [2].

LOKUS is an online survey tool that seeks to measure an individual's level of awareness, interest and use of new knowledge generated in the context of technological innovations, through research (R), development (D) and/or production (P) activities. New knowledge is viewed as an output from these three different yet similarly systematic methods, therefore characterized as knowledge existing in three alternate states: 1) Discoveries in conceptual form, generated by research (R) through scientific methods; 2) Inventions in prototype form generated by development (D) through engineering methods; 3) Innovations in commercial form generated by production (P) through industrial methods [3]. Thus, stakeholders interested in new knowledge in any of its three alternate states are legitimate audience of this survey tool.

The Need

Impetus for the development of LOKUS came from growing requirements for accountability in government sponsored "R&D" programs and the need to document return on investment in these programs [4,5,6]. Programs are expected to demonstrate evidence that the outputs (i.e., concepts, prototypes, products/services) of the projects they sponsor are being put into use by stakeholders external to the project. Stakeholder use of outputs represents outcomes, which, in turn, are expected to yield impacts of either a social or economic nature. Documenting outcomes was never more important than in these times of contracting resources, where government programs must compete for a share of available funds.

As a worldwide response to these governmental and societal calls for accountability, scholarly attention has turned to the challenge of assessing impacts, particularly from R outputs [7] given the concentration of public resources around R activities and institutions. Scholars have widely varied in their views of indicators of such impact [7, 8], that span social, economic, environmental and even cultural benefits in systems level analyses. Examples include academic and economic returns to research institutions - such as capacity building –and more broadly, regional economic growth, which convolute the analysis because these indicate impacts from the influx of public funding (an input) rather than from R discoveries (an output). Various views if impact have guided measurement approaches, such as the multi-dimensional view in the Payback framework [9] and the Productive Interactions view, focused on players in the research-to-societal benefits process [10]; with a varying range of measures from quantitative - such as bibliometrics, patents, licenses and royalties to qualitative that employ anecdotes regarding particular applications (e.g., Internet, GPS), or narratives that seek to enlighten ongoing quest for broader social benefits. In light of such divergence in defining impact from research, some scholars have pointed out the need for short term measures that are robust predictors of longer term impacts [11].

The need for short term metrics as a pathway to assessing longer term impacts has been recognized in the social and healthcare arenas, through attention to indicators such as *knowledge utilization* and *reach* of knowledge [12,13,14]. Often viewed broadly and synonymously with research utilization [15], knowledge use is embraced both by scholars and funding agencies [16,17,18] as a useful indicator for tracking impact from projects, including specific contexts such as technology oriented R, D or P projects. This has called impact achievement to the forefront in related literature as an issue adjunct to impact assessment. The existence of a *research-to-practice* gap has been recognized as a key barrier to achieving such impact, and indeed, the concept of knowledge translation (KT) is a response to the need for closing this gap in order to ensure impact from R [19,20,21,22,23]. Funding agency efforts to close the gap have supported KT strategies that identify knowledge use as a key indicator of research impact and are geared to achieve increased use of knowledge by stakeholders.

The challenge to creating robust measures, or rather to defining the construct of knowledge use in the context of government sponsored "R&D" programs is two-fold. First, the concept of knowledge extends beyond that output by the R process; in fact, impacts are as (or more) likely to arise from the outputs of D as from those of R [24]. The methods of R and of D are known to intersect when supporting applications of technology-oriented knowledge [25]. Furthermore, to the extent this knowledge is expected to spur innovations, a third method – industrial production P– comes into play in converting "R&D" outputs into commercial products and services [26]. Thus, as pointed out earlier, within the context of technology-based innovations, the outputs from each method R, D or P can be collectively viewed as knowledge, but individually viewed as knowledge in different states [3].

Second, the technological innovation context has a special bearing on the concept of use by the stakeholders. The transformation of knowledge from one state to other requires a particular knowledge output to be exchanged between the source which applied one method, and the recipient which applies a different method. The exchange process is itself different for each state of knowledge. Discoveries from R are exchanged through the knowledge translation (KT) process, i.e., a dynamic and iterative process that includes synthesis, dissemination, exchange and ethically-sound application of knowledge [19]. It is focused on effective communication of value. Inventions from D are exchanged through the technology transfer (TT) process, i.e., a process for applying known technologies to new and novel applications [27, 28]. It is focused on legal ownership and control over value. Goods/services from P are exchanged through commercial transactions focused on monetary payment for value [3]. Each exchange of knowledge represents knowledge use, or an outcome that leads to impact; so it is an important metric in tracking/predicting interim and ultimate benefits from technology based innovations. The metric should validly cover the use of knowledge by multiple stakeholders interested in the alternate states of knowledge.

Furthermore, as Sudsawad summarizes in her literature review, knowledge can be used in three ways– *instrumental use* involving direct and specific applications of the knowledge, including its transformation; *conceptual use*, for general information and enlightenment, though not necessarily for action; and *symbolic use* to support predetermined positions, such as a political tool to legitimize opposition or practice [23, 29, 30]. While the impact metrics discussed in prior literature focus on the use of R outputs, and therefore imply *knowledge use*, they limit themselves to *conceptual* or *strategic uses* to the exclusion of *instrumental use.* For example, bibliometrics are based on citations of an R output, which record how many times the new knowledge is acknowledged (conceptual use) or how often it is used to defend or refute other viewpoints (strategic use). This metric does not involve a follow up of the knowledge in transformation to more concrete states (discovery turned into prototype and then into product by industry, as an example) in order to document benefits (to consumer) at the end of the outcome chain. Yet, in light of the foregoing, this *instrumental use* is critical as an outcome measure contributing to the impact expected. Sponsors and grantees engaged in technology oriented R, D or P projects who seek context-specific indicators, find limited guidance in the prevailing literature on impact measurement which focuses exclusively on R. Hence the urgency to fill the special need for a measure of K use in the technology innovation context.

The Context of Tool Development

The Center on Knowledge Translation for Technology Transfer (KT4TT) at the University at Buffalo provided an opportunity to respond to the above need under sponsorship by the National Institute on Disability and Rehabilitation Research (NIDRR). Charged with the mission of developing best practices in KT in the context of technological innovation for beneficiaries with disabilities, the center has been conducting a series of randomized controlled trials (RCTs), to evaluate KT interventions designed to communicate outputs (new knowledge) from technology oriented R, D or P projects to their stakeholders [31]. In order to draw valid inferences about intervention effectiveness in terms of increasing the use of the new knowledge, the RCTs urgently needed a sound measure of *knowledge use*. In turn, they also represented an opportunity to develop such a measure; thus the first RCT in the area of Augmentative and Alternative Communications (AAC) technology provided the test bed for LOKUS. Details of design and implementation of the RCTs are presented elsewhere [31, 32].

Method

The conceptual basis for the tool to be developed was derived from a focussed search through relevant literature – a search either for a ready measure of Knowledge use or for related concepts or frameworks that support construction of such a measure. The following considerations guided the search.

As with any evaluative procedure, both merit (i.e., psychometric soundness of the measure), and worth (i.e., its relevance or value to the interested stakeholders) are important in building a measure of knowledge use [33,34]. Instrument merit, closely tied to its construct validity, implies valid and reliable coverage of the concepts *knowledge* and *use* in the sense discussed above. The design implications include coverage of the full range of responses from multiple stakeholders, based on the consideration that: (a) different stakeholders may be interested in different states in which the knowledge may be embodied – i.e., concept, prototype or commercial product; (b) these stakeholders may use the knowledge in any of the three ways discussed earlier – instrumental, conceptual or symbolic [23,29,30], or in any combination amongst the three [35]; (c) legitimate respondents include beneficiaries (i.e. end users of technology-based devices and services) and intermediaries who contribute to commercial availability of products/services to beneficiaries (i.e., policy makers, clinicians/practitioners, manufacturers/suppliers, applied researchers/developers and transition brokers like attorneys and employers); and additionally, (d) four types of knowledge outputs are potentially generated by technology-oriented R, D or P projects: 1) Standards or guidelines such as clinical protocols or performance requirements; 2) Instruments or Tools used for measurement or fabrication in laboratories; 3) Freeware downloadable such as software packages or plans for do-it-yourself construction; 4) Commercial devices or services sale and distribution in the marketplace [31]. Thus the measure should be generic enough to accommodate responses from all these knowledge stakeholders, yet specific enough to distinguish among varied users.

Instrument worth, on the other hand, refers to the measure's value or utility to its primary stakeholders, hence implying feasibility of its application by investigators and funding agencies. The measure should be able to: (a) yield sweeping evidence of impact from the large volume of sponsored project outputs, and possibly some data useful for individual project improvement and (b) be logistically feasible and cost effective.

Taken together, the criteria of merit and worth address the Joint Committee standards for evaluation quality, especially *accuracy*, *utility* and *feasibility* [33, 34].

Results and Discussion

As discussed in related literature the concept closest to *knowledge use* appears to be *innovation use.* It has held the attention of social and health care program managers alike, because of its value as an indicator of program effectiveness. Everett Roger's model of innovation use is one of the earliest and most widely used in literature [36]. Its five stage process of innovation adoption: knowledge (awareness), persuasion, decision, implementation and confirmation, is particularly relevant to the KT process, and most closely reflects the basic steps of awareness, interest and use generally implied in many studies discussed below.

Sudsawad's [23] comprehensive review of studies focused on KT models, methods and measures, is an insightful source of measures of use, of research use in general, and of specific research study findings, [30,37,38,39,40]. It includes several measures based on Rogers' model of innovation adoption, although most do not fit the criteria relevant to our context. Landry and colleagues [37, 40] proposed measures that collected data from the perspective of knowledge producers and policymakers, but not of knowledge users. The Nursing Practice Questionnaire (NPQ) by Brett [41], despite its promise, lacks sufficient detail for in-depth examination of knowledge use.

The Levels of Use (LoU) Scale offers a model that explores depth of use, by measuring cognitive behaviors related to the innovation adoption process within a framework consisting of eight levels, and seven categories within each level, with decision points between levels. [42,43]. The levels are defined as: (0) non-use; (I) orientation; (II) preparation; (III) mechanical use; (IVA) routine use; (IVB) refinement; (V) integration and (VI) renewal. The category break down under each level includes user behaviors referring to knowledge (i.e., knowing), acquiring information, sharing, assessing, planning, status reporting and performing. Although not explicitly stated as such, it overlaps with and expands upon Roger's stages of innovation adoption. Table 1 shows an overall correspondence between the two sequences. According to Sudsawad [23], the LoU scale is "one of the most comprehensive in measuring use" (P. 27).

Table 1: Hall and Colleagues' LoUs [43] and Roger's Stages of Innovation

Hall and Colleagues' LoUs	Roger's Stages of Innovation Diffusion
Level 0 Non-Use: User has little or no knowledge of the innovation, has no involvement with the innovation, and is doing nothing toward becoming involved.	
	Knowledge: Individual is first exposed to an innovation but lacks information about the innovation. During this stage of the process the individual has not been inspired to find more information about the innovation.
Level I Orientation: User has acquired or is acquiring information about the innovation and/or has explored or is exploring its value orientation and its demands upon the user and the user system.	**Persuasion:** Individual is interested in the innovation and actively seeks information/ detail about the innovation
	Decision: Individual takes the concept of the change and weighs the advantages/disadvantages of using the innovation and decides whether to adopt or reject the innovation. Due to the individualistic nature of this stage Rogers notes that it is the most difficult stage to acquire empirical evidence (Rogers 1964, p. 83).
Level II Preparation: User is preparing for first use of the innovation.	
Level III Mechanical use: User focuses most effort on the short-term, day-to-day use of the innovation with little time for reflection. Changes in use are made more to meet user needs than client needs. The user is primarily engaged in a stepwise attempt to master the tasks required to use the innovation, often resulting in disjointed and superficial use.	**Implementation:** Individual employs the innovation to a varying degree depending on the situation. During this stage the individual determines the usefulness of the innovation and may search for further information about it.
Level IVA Routine: Use of the innovation is stabilized. Few if any changes are being made in ongoing use. Little preparation or thought is being given to improving innovation use or its consequences.	**Confirmation:** Although the name of this stage may be misleading, in this stage the individual finalizes his/her decision to continue using the innovation and may end up using it to its fullest potential
Level IVB Refinement: User varies the use of the innovation to increase impact on clients within immediate sphere of influence. Variations are based on knowledge of both short- and long-term consequences for clients. **Level V Integration:** user is combining own efforts to use the innovation with the related activities of colleagues to achieve a collective impact on clients within their common sphere of influence. **Level VI Renewal:** the user re-evaluates the quality of use of the innovation, seeks major modifications or alternatives to the present innovation to achieve increased impact on clients, examines new developments in the field, and explores new goals for self and the system.	

The scale was developed to measure innovation use in educational settings, as part of the Concerns Based Adoption Model (CBAM) [44,45]. The authors consider levels as overall sequential; however individual movements are not lock-step developmental [43]. The operational model requires assignment of respondents to categories and levels through systematic qualitative interviewing. The authors reported a validity of 0.98 for the LoU interview ratings as correlated with ethnographer ratings; and a correlation of 0.65 with independent interview protocol ratings. Their recommended procedures for interviewer reliability estimates are "rater-overall" percent agreement as well as Cronbach's alpha [43]. A subsequent study by Colbert [46] reported a concurrent validity of 0.71 between the LoU interview and an observational inventory (LoUOI) developed for science curriculum adoption. The authors consider the LoU scale as generic and applicable to innovations in general, and have documented multiple applications of the LoU scale to document changes across a variety of innovations [43].

Another useful framework for measuring knowledge use is the *reach, efficacy, adoption, implementation* and *maintenance* (RE-AIM) model, proposed in the specific context of KT in healthcare [12,13]. Notably, the dimensions overlap and expand upon Roger's stages of innovation adoption, but differ from the cognitively defined LoU levels. The dimension of *reach* is unique and points to the importance of capturing changes at the lower levels of the scale i.e., from Non-awareness to higher levels.

The LoU scale appears very useful as a measure of knowledge use. In concept, the levels of use overlap with Roger's stages of adoption, where the levels I and II correspond to the persuasion stage and the last five levels (III to VI) to the adoption stage. While Roger proposes decision as an explicit stage before adoption takes place, the LoU scale includes decision points between levels. Its two-dimensional framework of levels and categories, the LoU chart, further makes it suitable to capturing awareness, interest and use of new K generated by R (or D or P) projects, by providing the needed expansion of Roger's stages, yet remaining generic enough to accommodate multiple stakeholder responses. And it can provide a basis for interpreting knowledge use behaviors analytically. However, this calls to question an assumed transferability of the LoU measurement model to the context of knowledge use. Both its framework and its operational model of qualitative data capturing and analysis model have been shown to work in the context of implementing ready innovations – for example, a new curriculum to be adopted by teachers; and in fact, the LoU applications have typically focussed on user behavior during implementation in an organizational setting (such as classroom), where the innovation had been introduced (i.e., installed or had been chosen). In contrast, *knowledge use* in the context of technological innovations is understood more broadly to include any transformation in the path to innovation (i.e., concept to prototype to commercial products/services) as part of the adoption process; it also involves the challenge of *reaching* multiple stakeholder audiences that are not always part of an organized implementation effort. Evidently, the LoU model would not be the most feasible in terms of engaging the wide range of audience spread across organizations, roles and sectors.

All the same, the infeasibility of replicating the LoU measurement model in our context does not diminish the merit of the LoU framework of levels-and-categories as a valid basis for designing a new tool that can address the full range of relevant knowledge use attributes. The new tool, however, should fulfil the quality criteria of tool utility and feasibility.

Conclusion

Considering the potential offered by the LoU framework to support the development of a measure of knowledge use, and considering that knowledge producers need a feasible tool to collect data and track outcomes from their knowledge outputs, we conclude by favouring the development of a new instrument for the purpose outline in this paper. We further conclude in favor of the following steps that would support and ensure the merit and worth of such an effort: (1) Initial guidance from the LoU behavioural framework while generating behaviors of knowledge use. This would provide incremental coverage of the knowledge use process through items measuring levels; additionally it would have the capability of probing and expanding upon them through the category measures. This offers an alternative use of the LoU elements, given that the intended use of the LoU operational model is infeasible in our context - i.e., the ability to use the categories for prior qualitative probing as a basis for identifying a respondent's level of use. (2) Empirical validation in the technology innovation context leading to systematic modification in content and format is necessary to define and obtain the intended tool; and (3) A combination of an online survey approach, a questionnaire format and items requiring self reporting would reduce the burden on respondents and data collectors alike. Such an approach, while limiting the robustness of the instrument relative to original LoU model, would satisfy the criteria of utility to technology R&D project investigators and their sponsors that are in urgent need of such a measure. At the minimum, the measures of level can provide them a birds' eye view of outcomes through the level items and ideally, the category items will permit them to probe in depth into user context and offer technical assistance in order to increase or to sustain knowledge use.

Authors' contributions

Dr. Vathsala Stone introduced the problem and the context of development of LOKUS and contributed to concept development through the method, results and conclusions sections.

Mr. Joseph Lane contributed to the rationale leading to the tool's conceptualization and elaborated the key concepts underlying knowledge in the context of technological innovations and implications of its use for the tool's purpose and scope.

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