International Perspectives on Social Policy, Administration, and Practice

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Knowledge, Innovation, and Impact

A Guide for the Engaged Health Researcher

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Sixsmith, Sixsmith, Mihailidis, Fang - Knowledge, Innovation, and Impact: A Guide for the Engaged Health Researcher

This book provides researchers with a straightforward and accessible guide for carrying out research that will help them to generate good science with real-world impact. All too often researchers excel at research design, data collection and analysis, but lack the knowledge and ability to commercialize or mobilize the outcomes of their research. Moreover, there is a lack of training and educational resources suitable to support researchers to navigate large, complex research teams composed of the wide range of disciplines and experience that are becoming typical. To improve the process of research into real-world impact, the book draws on the editors' experience of leading the AGE-WELL Network of Centres of Excellence and offers practical advice in three areas central to AGE-WELL (Aging Gracefully across Environments using Technology to Support Wellness, Engagement and Long Life): transdisciplinary team working; co-creation approaches and methods; and, commercialization and knowledge mobilization. The format of the book is straightforward and emphasizes the practicalities of how to undertake the kinds of activities that researchers need to engage in if they are serious about achieving impact. There are concise chapters on key practical topics; worked examples; case studies; and associated learning activities. Written in plain language, this valuable resource will help guide researchers through the process of research-driven innovation.

Contents

Part I Thinking About Impact

1 Introduction: The Engaged Health Researcher—Why and How to Use This Book 3
Andrew Sixsmith, Judith Sixsmith, Alex Mihailidis, and Mei Lan Fang

2 Thinking Innovatively About Innovation Research 9
Andrew Sixsmith, Alex Mihailidis, Mei Lan Fang, and Judith Sixsmith

3 Understanding the Product Innovation Pathway 17
Andrew Sixsmith, Judith Sixsmith, Mei Lan Fang, and Alex Mihailidis

4 An Introduction to Transdisciplinary Working 25
Alisa Grigorovich, Pia Kontos, Judith Sixsmith, Mei Lan Fang, and Mineko Wada

5 Knowledge Mobilization for an Engaged Researcher 33
Igor Gontcharov, Karen Kobayashi, and Amanda Grenier

Part II Working Collaboratively

6 Building Partnerships and Co-creating with Diverse Stakeholders 47
Mei Lan Fang, Alisa Grigorovich, Mineko Wada, Pia Kontos, and Judith Sixsmith

7 Case Study: A Community-Based Approach to Developing Optimal Housing for Low-Income Older Adults 59
Mei Lan Fang, Judith Sixsmith, Ryan Woolrych, Sarah Canham, Lupin Battersby, Tori Hui Ren, and Andrew Sixsmith

8 Learning Activity: Taking the Guesswork Out of Stakeholders—Creating an Actor Model 65
Andrew Sixsmith

9 Working Together as a Transdisciplinary Team 69
Judith Sixsmith, Mei Lan Fang, Alisa Grigorovich, Mineko Wada, and Pia Kontos

10 Learning Activity: Essentials of Teamwork 77
Euson Yeung

11 Engaging *Hard-to-Reach*, *Hidden*, and *Seldom-Heard* Populations in Research 81
Shannon Freeman, Kelly Skinner, Laura Middleton, Beibei Xiong, and Mei Lan Fang

12 Case Study 1: The Nak'azdli Lha'hutit'en Project—Creating Digital Stories with Elders and Youth in Nak'azdli First Nation 93
Shannon Freeman, Kelly Skinner, Jenny Martin, and Simone Hausknecht

13 Case Study 2: Engaging Youth in a Needs Assessment for Programming and Evaluation 97
Kelly Skinner, Kristin Burnett, Erin Pratley, Barbara Parker, and Brenda Dovick

14 Learning Activity: Learning How to Include *Hard-to-Reach*, *Hidden*, and *Seldom-Heard* Populations in Research 101
Shannon Freeman and Martha MacLeod

15 Building Relationships with *Hard-to-Reach*, *Hidden*, and *Seldom-Heard* Populations in Research 107
Shannon Freeman, Kelly Skinner, Laura Middleton, Beibei Xiong, and Mei Lan Fang

16 Case Study: Creating Integrated Working Relationships with Frail Older People—The Smart Distress Monitor Project 117
Judith Sixsmith

17 Addressing Real-World Problems Through Transdisciplinary Working 121
Mineko Wada, Alisa Grigorovich, Pia Kontos, Mei Lan Fang, and Judith Sixsmith

18 Case Study: Practical Steps in Transdisciplinary Team Working—The Enable-Age Project 131
Andrew Sixsmith

19 Education and Training for Innovation and Impact 135
Samantha Sandassie and Euson Yeung

20 Case Study: Teaching Innovation in Action—the Case of the AGE-WELL EPIC Summer Institute 145
Samantha Sandassie and Euson Yeung

21 Building an Inclusive Research Culture 149
Debbie Baldie, Caroline A. W. Dickson, and Judith Sixsmith

Part III Designing Together

22 Reviewing the Literature 165
Steve MacGillivray

23 Co-production Methods in Health Research 175
Arlene J. Astell and Deborah I. Fels

24 Case Study: Co-creating NANA (Novel Assessment of Nutrition and Ageing) with Older Adults Living at Home 183
Arlene J. Astell, Tim Adlam, Faustina Hwang, and Liz Williams

25 Learning Activity: Structured Brainstorming for the Co-production of Real-World Products 187
Carolyn Sparrey

26 Doing Research Ethically 191
Judith Sixsmith and Andrew Sixsmith

27 Ethics of Health Research and Innovation 203
Rosalie H. Wang and Jerome Bickenbach

28 Design Tools: Transforming Ideas into Products 211
Piper J. Jackson and Amy S. Hwang

29 Cross-Cultural Adaptation of Existing Health Technologies 221
W. Ben Mortenson, Claudine Auger, Garth Roston Johnson, and Manon Guay

30 Iterative Prototyping and Co-design 231
Daniel Southwick, Gabby Resch, and Matt Ratto

31 Case Study: Nia Technologies—Validating Your Solutions 239
Matt Ratto, Daniel Southwick, and Gabby Resch

32 Learning Activity: The Design Dash—Bringing Your Abstract Ideas to Life 243
Gabby Resch, Daniel Southwick, and Matt Ratto

33 Evaluation of Health Technology Solutions 251
Jay JH Park, Patrick Boutet, Gabrielle Serafini, and Richard T. Lester

34 Case Study: WelTel Solution—An Interactive SMS-Based Mobile Phone Support for Patient-Centered Care 261
Jay JH Park, Gabrielle Serafini, and Richard T. Lester

Part IV Creating Research Products

35 Effective Communications 269
Margaret Polanyi, Dorina Simeonov, and Elise Johnson

36 Case Study 1: Reaching a Wide Audience—Rate My Treads 279
Erica Di Maio

37 Case Study 2: Writing Stuff for the Real World 283
Andrew Sixsmith

38 Learning Activity: Getting Started Pitching Your Innovation 287
Richard McAloney and Leo Mui

39 Informing Policy Through Partnerships 291
Dorina Simeonov, Candice Pollack, and Jenna Roddick

40 Case Study: From Stakeholder Engagement to Policy Change—Lessons from Alberta's Bill 210, the Missing Persons Amendment Act (Silver Alert) 301
Lili Liu, Noelannah Neubauer, and Christine Daum

41 Navigating Policy, Regulatory, and Health System Landscapes 305
Maggie MacNeil, Don Juzwishin, and Paul Stolee

42 Commercializing Research Innovations: An Introduction for Researchers 315
Lupin Battersby and Pooja Viswanathan

43 Case Study 1: Blind Spot Sensors for Wheelchairs—Increasing Access to Independent Mobility 325
Pooja Viswanathan

44 Case Study 2: The Java Project—The Evolution of Peer Support and Mentoring in Residential Care 331
Kristine Theurer

45 Dealing with Intellectual Property at the Early Stages 335
Richard McAloney, Emanuel Istrate, and Jeffrey Buchholz

46 Case Study: Managing Intellectual Property with an Institution 347
Richard McAloney

47 How to Implement an Integrated Knowledge Mobilization Approach 351
Dorina Simeonov, Karen Kobayashi, and Amanda Grenier

48 Learning Activity: Embedding Healthcare Technologies in Real-World Contexts—Developing the Scale-Up, Spread, and Sustainability of Assistive Technologies in Health Systems 361
Karen M. Kobayashi, Amanda Grenier, and Igor Gontcharov

Correction to: Thinking Innovatively About Innovation Research C1

Glossary 365

Index 387

Abbreviations

3D	Three dimensional
AGE-WELL	Aging Gracefully across Environments using Technology to Support Wellness and Long Life
AGE-WELL NCE	Aging gracefully across environments using technology to support wellness, engagement and long life Network of centres of excellence
AI	Appreciative inquiry
AI	Artificial intelligence
ANOVA	Analysis of variance
APPTA	Advancing policies and practices in technology and aging
ART	Antiretroviral therapy
AT	Assistive technology
CABHI	Centre for Aging and Brain Health Innovation
CAD	Computer-aided design
CAM	Computer-aided manufacturing
CARE	Case reports
C-ASAP	Community area silver alert program
CBPR	Community-based participatory research
CCBRT	Community Based Rehabilitation in Tanzania
CEAL	Challenging Environment Assessment Labs
CHEERS	Consolidated Health Economic Evaluation Reporting Standards
CIHI	Canadian Institute of Health Information
CIHR	Canadian Institutes of Health Research
CIPO	Canadian Intellectual Property Office
CLRI	Ontario Centres for Learning, Research and Innovation in Long-term Care
CMA	Canadian Medical Association
CONSORT	Consolidated Standards for the Reporting of Trials
COREQ	Consolidated criteria for reporting qualitative research
CoRSU	Comprehensive Rehabilitation Services Uganda

CRPD	United Nations' Convention on the Rights of Persons with Disabilities
CSA	Canadian Standards Association
CSPO	Cambodian School of Prosthetics and Orthotics
CTEF (Simon Fraser University)	Community Trust Endowment Fund
EMRs	Electronic medical records
EQUATOR	Enhancing the QUAlity and Transparency Of health Research
ERB	Ethical review boards
FNIGC	First Nations Information Governance Centre
GBP	British Pound Sterling
GDPR	General data protection regulations
HIV	Human immunodeficiency virus
HTA	Health Technology Assessment
ICTs	Information and communication technologies
IDRC	International Development Research Centre
IECs	Independent ethics committees
iKT	Integrated Knowledge Translation
IP	Intellectual property
IRBs	Institutional review boards
KITE	Knowledge, Innovation, Talent, Everywhere
KM	Knowledge mobilization
LBGTQ+	Lesbian, gay, bisexual, transgender, queer, and questioning
LIFE	Learning information for future empowerment
LMICs	Lower and middle income countries
LTBI	Latent tuberculosis infection
LTC	Long-term care
MAREP	Murray Alzheimer Research and Education Program
MHAC	Mental Health Awareness Club
mHealth	Mobile health
MHNA	Mental health needs assessment
MMA	Maximum achievable angle
MNDA	mutual nondisclosure agreement
MRI	Magnetic resonance imaging
MSFHR (I2C)	Michael Smith Foundation for Health Research (British Columbia)–Innovation to Commercialization program
NANA	Novel Assessment of Nutrition and Ageing
NASA	National Aeronautics and Space Administration
NASSS	Nonadoption, abandonment, scale-up, spread, and sustainability framework
NDA	Non-disclosure agreement

NIDILRR	National Institute on Disability, Independent Living, and Rehabilitation Research
NIDILRR	National Institute on Disability, Independent Living, and Rehabilitation Research
NPL	Natural language processing
NRC-IRAP	National Research Council Industrial Research Assistance Program
NSERC	National Sciences and Engineering Research Council of Canada
OARC	Ontario Association of Residents' Councils
OCAP	Ownership, Control, Access, and Possession
P&O	Prosthetics and orthotics
PCHT	Point of Care Healthcare Technologies project
PCT	Patent Cooperation Treaty
PIP	Product Innovation Pathway
PRISMA	Preferred reporting items for systematic reviews and meta-analyses
PRISMA-P	Preferred reporting items for systematic review and meta-analysis protocols
QMU	Queen Margaret University
R&D	Research and development
RCTs	Randomized clinical trials
REBs	Research ethics boards
ROI	Return on investment
RQ+	Research Quality Plus
SA	Shareholders' agreement
SAFER	Shelter aid for elderly residents
SFU	Simon Fraser University
SH	Shareholders
SMART	Specific; measurable; attainable; relevant; timebound
SMS	Short message service
SPIRIT	Standard protocol items: recommendations for interventional trials
SQUIRE	Standards for QUality Improvement Reporting Excellence
SRQR	Standards for Reporting Qualitative Research
SSHRC	Social Sciences and Humanities Research Council of Canada
STAR	Science and Technology for Ageing Research (STAR) Institute (at Simon Fraser University)
STARD	Standards for Reporting Diagnostic accuracy studies
STROBE	Strengthening the Reporting of Observational Studies in Epidemiology
TATCOT	Tanzania Training Centre for Orthopaedic Technologists
TCPS2	Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans
TDW	Transdisciplinary working
ToR	Terms of reference
TRIPOD	Transparent reporting of a multivariable prediction model for individual prognosis or diagnosis
TRI-UHN	Toronto Rehabilitation Institute-University Health Network

TRI-UHN	Toronto Rehabilitation Institute-University Health Network
TRL	Technology Readiness Level
UHN	University Health Network
UK	United Kingdom
UML	Unified Modelling Language
UNBC	University of Northern British Columbia
USPTO	US Patent and Trademark Office
UW	University of Waterloo
UX	User experience
WHO	World Health Organization
WIPO	World IP Organization

Part I
Thinking About Impact

Chapter 1
Introduction: The Engaged Health Researcher—Why and How to Use This Book

Andrew Sixsmith, Judith Sixsmith, Alex Mihailidis, and Mei Lan Fang

Turning Ideas into Impact

The world of research has changed. The idea of an academic working alone in his or her ivory tower, isolated from the distractions of the outside world, is becoming a thing of the past. More and more, researchers are working in teams in large collaborative projects, where the funders have high expectations that the research will deliver tangible social and economic benefits. While impact is a worthwhile objective, achieving it in practice is a complex process, and many researchers are unprepared for the challenge of turning their ideas into real-world products, policies, practices, and services. How do you work effectively in a large team? How do you involve stakeholders and end users in your research? How do you *do* commercialization and knowledge mobilization? How do you manage relationships and expectations effectively with a range of different, nonacademic stakeholders? How do you reconcile these additional actions with your academic goals and activities? Researchers are increasingly expected to do more than traditional research tasks, but in our experience there has been limited practical support. The aim of this book is quite straightforward—to bring together current knowledge and experience to provide researchers with an accessible guide to how to carry out translational, *engaged* health research that will help to turn ideas, knowledge, and technologies

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into actions and outcomes that can have positive real-world impact on societies and economies.

Overview of the Book

The book is divided into four parts, starting by looking at the underlying ideas around engaged health research and then moving on to practical *how-to* chapters that constitute the main part of the book.

Part I: Thinking About Impact

This part introduces and discusses the underlying ideas and principles behind engaged health research—the why, what, and how of research-driven innovation. A major theme in this book is to plant the seed for us to start thinking about knowledge mobilization, innovation, and impact as being part of all stages of the research, even at the initial conceptual stages. The problem is how do we most effectively build these new activities into our research? For example, how do we work together with a diversity of external stakeholders to jointly conceptualize the problem area of our research? How should we co-design the project and what methods do we need to employ in knowledge mobilization or commercialization? How do we determine the expertise needed in the project? What do we mean by innovation and impact? How do we work toward impact as the goal? What are the barriers and opportunities? This part introduces the three ideas that we feel are crucial to an integrated, more holistic approach to knowledge mobilization: transdisciplinary working, co-production research, and effective outreach. Part I sets the scene for the rest of the book. The following three parts provide the practical *how-to* guides on key topics relating to the three pillars of engaged research.

Part II: Working Collaboratively

This part is about working collaboratively on the complex problems that exist within the health field. It is also about rethinking these problems and creating disruptive ideas and solutions. As well as breaking down the disciplinary silos that exist in academia, it requires researchers to work with stakeholders and communities in a meaningful way, as equal partners in the innovation process. The principle is fine, and there are many good articles that introduce the ideas behind transdisciplinarity and other forms of collaborative working, but what is less available are resources on how to do this effectively in practice. This part covers topics such as establishing the expertise base needed in the project; building authentic and meaningful

partnerships; putting in place partnership mechanisms that support strong and enjoyable teamwork, introducing positive frameworks to support the integration of ideas across disciplines and sectors; working in ways which are inclusive of hard to reach or seldom heard groups; and minimizing the negative aspects of power relations within research. Issues of education and training are also covered, ensuring that the necessary social and teamworking skills are in place, thereby building capacity for future collaborative research. However, capacity building for the future is only part of the story for developing collaboratives frames for research. Developing a flourishing, person-oriented, and vibrant research culture is also necessary, a culture that is open to self-reflection and critical appraisal and most importantly is respectful of researchers and the participants in research.

Part III: Designing Together

This part focuses on research methods and is about involving stakeholders and end users as co-producers and co-creators of solutions. Researchers often have specialist knowledge and skills, for example, in the engineering or computer science fields, but if this expertise is to be applied successfully, solutions need to be grounded in the everyday knowledge and expertise of the person, the participant, the patient, or the customer. The key is to avoid the technology-driven approach by involving users at all stages from concept, through development and into real-world evaluation and implementation. This part covers topics such as how to conduct a robust and rigorous review of existing knowledge; co-create health innovations together with their intended recipients; meaningfully engage stakeholders throughout the entire research process; facilitate the development and maintenance of valuable relations between knowledge creators and knowledge users during the prototyping stage; and conduct ethical research, particularly when working with vulnerable groups. Aligned with the key messages and goals of this book, the topics addressed in this part enable to us to better identify, understand, and respond to the needs, aspirations, and everyday lives of those we aim to serve and co-produce practical solutions through health research innovation that can ultimately be turned into real-world products and services.

Part IV: Creating Research Products

This part focuses on the very practical aspects of turning ideas, prototypes, and new practices into real-world products and services. Typically, these have been seen as activities that come after the research phase, or "end of project knowledge translation." This is the researcher's get-out-of-jail card that allows him or her to quietly forget about impact and move on to their next project. We argue that these activities need to be brought forward into all stages of the research. For instance, thinking

about commercialization or deployment right from the start will help to avoid building solutions that will inevitably fail. Visualizing what the final product might look like, who the customer is, and how much the product might cost are things that can be easily done, but have a big pay-off later on. This part covers topics such as how to effectively communicate with a wide audience, including other researchers, stakeholders, and partners; informing policy and influencing policy makers through research findings and appropriate methodologies, including how best to navigate the policy and health system landscapes; and, finally, topics around commercialization and knowledge mobilization, including important issues like dealing with intellectual property and integrated approaches to knowledge translation. All of these topics are meant to help researchers to work more closely with their teams, stakeholders, and partners in order to develop more effective solutions that will eventually be embedded in real-world contexts.

Each part has a brief introduction that gives the reader an overview about the ideas, themes, and connections they will find in the part and particular things that they might want to look out for.

How-to Chapters

The format of these how-to chapters is very simple and focuses on key topics, written in plain language that will help researchers through the process of research-driven innovation. The how-to chapters should help readers to visualize the kinds of non-core activities they need to engage in in order to ensure they progress toward innovation and impact. Each how-to chapter will address a key pillar in the translational research process. Each has a similar easy-to-follow format that will include the following sections:

The Challenge

Each how-to chapter addresses a specific topic or component in the translational research process: the issue, opportunity, or problem.

Key Ideas

The how-to chapters are short and to the point, and each provides an overview of 5–6 practical ideas relating to their particular challenge. It is helping the reader to start to answer the question: How do I go about X?

- What is the idea?

- What to do practical in terms of activities and outputs.
- May include a "box"—a very short case study or example to illustrate the idea.

Product Innovation Pathway (PIP) Model

This is an innovation in this book (more about this in Chap. 3). We want to help researchers to think about innovation at different stages of their project and not just something that is tacked on at the end. For example, researchers could be "doing commercialization" right at the start by carrying out an environmental scan of their market sector. However, commercialization activities further down the innovation pipeline will be very different. We have adapted and simplified the well-known TRL (technology readiness level) innovation scale into our own PIP model to make it more appropriate to the wide range of research projects. The model has five *stages*: innovative ideas; planning; development; testing; and outcomes. Every how-to chapter provides some pointers to the kinds of activities a researcher might have to engage in at various points in the PIP. These are guides and not blueprints, as every research project is likely to have its own objectives and dynamics that make it unique.

Finding Support

The book can only be an introduction to the complex world of translational research. It is important to provide readers with ideas for next steps and sources of further information: What should I do next? Who can I connect with to get help and support? Key resources, references and links to further reading.

Case Studies

Each of the how-to sections contains case studies that complement the how-to chapters in the book and will provide concrete examples to help the reader to visualize a key idea or approach in a very practical way: "…this is how we did it, and it worked really well…." The case studies will:

- Demonstrate how this example contributed to a successful translational research project.
- Provide examples of technologies and services at different stages of maturity.
- Illustrate major global health and healthcare challenges in the twenty-first century.

Learning Activities

As with case studies, the how-to chapters are supplemented by learning activities to reinforce learning about practical steps in a successful translational research project and relevant to a key health and healthcare challenge. The learning activities identify a key challenge and set out a particular problem, activity, and learning outcomes, as well as learning resources and any supporting materials needed in the activity.

The authors and editors of this book hope you find this book a helpful guide as we found it a rewarding experience putting it together with you in mind.

Chapter 2
Thinking Innovatively About Innovation Research

Andrew Sixsmith, Alex Mihailidis, Mei Lan Fang, and Judith Sixsmith

The Challenge: Innovation Is Complex

The title of this chapter highlights *innovation research*, rather than *innovation and research*. This is for two reasons. Firstly, we argue that research for its own sake is important, but having some kind of real-world benefit may also be an important objective. Improving our understanding of the way the world works is the goal of science, and using research knowledge to improve the lives and health of people is fundamental to the medical and health fields. However, turning research ideas into new products and services is often difficult. Excellent research may result in weak returns in terms of new enterprises, real-world products, and social and economic impact (Sixsmith, Mihailidis, & Simeonov, 2017).

Secondly, we suggest that "research" and "innovation" actually go hand in hand and we need to be smarter about the way we think about how they are connected. Sixsmith et al. (2017) argue that there may be an overly simplistic view of the innovation process in the research world. A recent report on fundamental science in Canada suggests that innovation is often seen as a straightforward linear process

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where "investments in basic and applied research should somehow cascade quickly into more goods and services along with healthier and happier populations" (Naylor Report, 2017, p. 63). However, innovation is a complex and often unpredictable process that doesn't lend itself to easy translation from research to real work applications. It is not just about developing new products or technologies because it is about thinking and doing things in new ways and implementing them as real-world solutions that will make a difference to individuals, society, and the economy. This is inevitably a messy process, where compartmentalizing the innovation process into discrete tasks and phases, such as basic research, solution development, and knowledge translation, is a flawed approach. Another flawed idea is that research results will naturally flow into implementation and adoption. The implication is that researchers need to be prepared to work in an iterative way, where the "flow" of the different parts of a project is interconnected and iterative, not necessarily in a linear direction.

The aim of this book is to shift our academic thought process toward thinking more actively about the innovation process within research contexts and to provide some practical approaches and tools that we hope will help people who work in the research community to take their ideas from "the lab into the real-world" or, more accurately, bring the world of research and the world of innovation closer together.

What Do We Mean by Innovation?

In getting to grips with the notion of innovation and impact, it is important to start defining some terms, for example, what do we mean when we talk about *innovation*? While there is no well-accepted definition, it could be said that innovation is about doing something in a new way that will have a positive benefit. Innovation might involve some kind of "invention," such as developing a new technology, but there are a few things to remember here. First, the invention itself is not the innovation because an innovation has to be implemented and used by people, businesses, etc. Second, innovation is not just about technology—it could be a process, service, policy, or a new business model. Third, innovation is a process and can look very different, depending on the context:

- Designing a new component in an existing product, system, or service may not require a huge investment or change. This *incremental innovation* is about small improvements that will make something more efficient, add value, reduce costs, etc. It might make an existing product more competitive or extend its shelf life in the market. Another approach is to apply expertise or solutions from one market or sector to another. While these may not look exciting, they typically account for most of the innovations that occur in business and services and can result in huge added value. They are also low risk, as they will be implemented and adopted within existing business processes. In the health sector, this could be a change to the way a service or procedure is organized and delivered that improves outcomes or reduces costs, but doesn't significantly impact on the organization as a whole. Even in areas such as pharmaceuticals, this low-key approach can be

seen as crucial to innovation and contribute to the development of "blockbuster" drugs (Wertheimer & Santella, 2005, p. 4).

- *Radical innovation* is about creating new industries or markets and typically comes from an entirely new technology, service, or procedure. Obvious examples here are the telephone and the internal combustion engine that gave rise to the telecommunications and automotive industries in the twentieth century. The most radical innovation here was not necessarily the telephones and cars themselves but the communications networks and mass production that turned luxury products into mass-market products. Examples from the health sector include the improved sanitation and building of fever hospitals in the early twentieth century to control the spread of infectious diseases. These fever hospitals were in turn rendered redundant with the widespread introduction of vaccines and antibiotics in the mid-twentieth century. Taken together these radical innovations saw the eradication of many of the killer infectious diseases that were common throughout history.
- *Disruptive innovation* is about a new technology or process that significantly changes an existing market or process. These disruptive innovations often come from entrepreneurs or small businesses, rather than large businesses or established organizations (where existing investments and processes can produce inertia). Disruption is about effect and impact, such as creating a new market or changing the way people or an organization does something. An example of a disruptive innovation in the health sector is the implementation of laws banning smoking in public spaces and the positive impact that this has had on health outcomes and attitudes to smoking (Frazer et al., 2016).

Innovation as a Process

Innovation can also be a process that turns ideas into various tangible outputs that are then implemented and used. This concept is captured in the idea of the technology readiness level (TRL). The TRL defines the process of innovation as a series of stages of maturity from concept to implementation. We will talk about this further in Chap. 3 when we introduce the *Product Innovation Pathway* model that is used to organize many of the ideas and methods discussed in this book.

In any research project that aims to create a *product*, it is useful to think of *levels*: ideas-planning-development-testing-implementation. These levels have different requirements and dynamics. For example, *ideas* might be about defining a problem, establishing market need, or coming up with a range of potential solutions, while *testing* might require a trial of a new device or intervention. But importantly, this should be seen as an iterative process, where a project progresses in small, related actions similar to a learning process. Indeed, outcomes from one part of a project might require the research team to revisit previous actions. However, some of the things that we often see as part of a discrete phase of working might be a useful part of other phases of a project, e.g., thinking about markets and the implementation process could be something that is addressed even at early stages of a project.

Where Does Research Fit in the Innovation Process?

If we want research to result in innovation, then the research itself must be innovative in the way it is conducted. This is one of the key messages when we discuss the idea of integrated knowledge mobilization and transdisciplinarity in later chapters. We often think of researchers in the health sector as people who inhabit laboratories, focused on developing new drugs or technologies that might someday be used by patients and the public. But health research covers a very wide set of activities and disciplines, ranging from basic science through to more applied sciences (e.g., computing science and engineering), social sciences, policy, business, and the humanities. In the health sector, all these can be part of innovation in many different ways and at different points in the process, for example:

- Understanding the problems and needs of people and patients.
- Requirements analysis and modelling.
- Visualizing and developing solutions and prototypes.
- Designing and developing new solutions.
- Organizing trials and evaluating outcomes.
- Providing evidence of best practice or outcomes.
- Evaluating long-term impact.
- Understanding barriers to adoption.
- Developing delivery models.
- Understanding the business environment.
- Communicating results of research.
- Developing models of clinical practice.
- Translating research knowledge into practical services.

Looking at these, we can immediately see an issue—researchers will be required to work outside of their typical disciplinary boundaries. They may also often require working with professional or experiential stakeholders within research projects themselves. For example, a project to develop some kind of assistive technology may require different research and sectoral expertise, such as a psychologist and an occupational therapist working with engineers. Crossing disciplinary and professional sector boundaries to working together collaboratively is a key part of this book.

Failure to Launch

Herzlinger (2006) points out that government investment in health-related research and development is second only to defense spending in the United States, while private sector R&D spending is probably in the tens of billions of dollars. Despite all of the investment, hard work, and the need for new solutions, too many of these efforts fail to launch. This gap between R&D and real-world deployment has been labeled the “valley of death” (Hudson & Khazragui, 2013). A quick Google search

of the expression "innovation valley of death" offers numerous possible reasons, including:

- Disjoint between academic processes and entrepreneurial processes.
- Failure to network outside the academic "comfort zone".
- Insufficient early-stage attention to the likely needs and decisions at a later stage.
- High cash demands versus low ability to raise it.
- Not enough emphasis on management, teams, and products.
- Assumption that pilots will naturally scale up to mainstream.

We often see impact case studies used to demonstrate where research has resulted in successful implementation and adoption of a new technology or process. These success stories are fine but are probably vastly outnumbered by unsuccessful ones that we tend to hear less about. Even where research leads to successful implementation, there is around a 17-year gap between getting research funding and when the results are put into practice in a real-world setting (Morris, Wooding, & Grant, 2011).

Box 2.1 A Personal Story

This is a fictionalized account but is typical of many projects that begin with good intentions but ultimately fail to deliver. The aim of the project was to develop a smart assistive environment to support people with cognitive impairments. The project was an international consortium of commercial, academic, and nonprofit partners and combined very significant public and private sector funding. Despite the investment, talent and hard work, a huge amount of research, and tech development, the project did not result in a product that could be eventually taken to market. Here are just some of the possible reasons:

- The initial project plan focused almost exclusively on technical aspects and technology development. Conversely, minimal resources and time had been earmarked for human aspects such as understanding user needs, working with them to develop prototypes, and then demonstrating and evaluating the solutions.
- The different aspects of the project were highly task-oriented and compartmentalized, making it difficult to communicate ideas and requirements between different teams.
- Motivations within the project varied greatly between different actors, often making it difficult to work in a cohesive way.
- Lack of knowledge around intellectual property and protection caused disagreement across partners on who owns what.
- The engineers and developers were too ambitious and unable to deliver key components, which undermined the viability of the overall system.
- The lack of a strong business case in the thinking around the system development.
- One of the major commercial partners pulled out due to changing priorities at management level.
- There were many different types of ethical challenges that created barriers for appropriate commercialization.

All large projects are going to face such challenges, but the key issue is that many of the problems encountered are not about the research or science but about aspects of the partnership such as organizational core values or changing personnel. Sixsmith et al. (2017) highlight a number of challenges to the research-into-innovation process. We will look at some of these and their implications.

Innovation in the Health Sector Is Particularly Challenging

While there is awareness that existing healthcare systems are increasingly unsustainable, there are many barriers to the sorts of innovations that might produce new ways to organize healthcare systems (Sebastianski et al. 2015). Indeed the healthcare sector could be seen as "innovation averse" (Herzlinger, 2006). A further dimension is that the problems and potential solutions are multifaceted and straddle different sectors. There are many of these so-called *wicked problems* (those complex, multilayered, and almost intransigent problems) within the health sector (Borger et al. 2017):

- Responding to the aging of populations.
- Obesity and unhealthy lifestyles.
- Inequalities in health.
- Pollution and ill health.

For example, the aging of populations is one of the most significant health challenges of the twenty-first century. Many of the authors in this book are part of the Canadian AGE-WELL Network of Centres of Excellence (Aging Gracefully across Environments using Technology to Support Wellness, Engagement and Long Life NCE) that is actively developing technology-based solutions to help seniors and caregivers to live healthily and independently and age in place. AGE-WELL has identified a number of challenge areas for innovations that go beyond health and healthcare services and include issues such as financial wellness, supportive design of homes and communities, and social connectedness (AGE-WELL, 2019). All of these are connected in determining a person's ability to live independently in later life.

The take-home message is that all these are challenges that go beyond traditional academic boundaries or policy areas and require joined-up thinking and creative solutions if we are going to tackle them. We can think of a *challenge* as an important but complex and difficult problem area that demands innovation and deployment of real-world solutions. A *challenge* is not just about problems; it may be about economic opportunities and making a positive contribution to society, government policy, and the economy. A *challenge* is also much more than a research question:

- Result in significant social and economic benefits.
- Difficult to accomplish yet offer hope of being ultimately solvable.
- Demand collaboration across disciplines and sectors.
- Should capture popular imagination and political support.

Innovation is Both Social and Technological

When we think about innovation, we typically think about new technologies, devices, and systems—the hardware and software of new technology. But in reality, innovation is about how we organize the way we do things or how we reorganize ourselves in order to adopt some new device or system. Some examples are:

- Development and implementation of policies.
- Organization of service delivery.
- Clinical and professional practice.
- Business processes.
- Cultural, attitudinal, and behavioral change.
- Training and capacity building.
- Enhancing receptor capacity.
- Development or enhancement of new theory.

Any of these may indeed be based on some kind of new technology, i.e., technology-enabled, but that is not the only aspect. A second point is that successful innovation probably requires doing things on multiple fronts. For example, if a new health technology is to be implemented, this might require new processes to be devised, as well as policy changes to support the funding and communication and training to ensure adoption. We talk about this more in Chap. 3, where we describe the different types of "products" that a project might need to think about in order to ensure that new solutions are implemented.

Conclusion

Changing the Way We Do Research

The take-home message is that if we are going to make a difference, then as researchers, we need to do things differently. Researchers are often in an invidious situation, where they are increasingly expected to deliver tangible social and economic outcomes but often without the training, support, and resources needed to do this properly. Indeed, the "publish or perish" culture that persists within academia acts as a perverse incentive away from non-core activities, such as knowledge mobilization or community outreach. Despite this, there is a lot that researchers in academic institutions can do to make their work more impactful. A major goal of this book is to provide some practical ideas and tools that can help. The approach is very much about a democratization of research and innovation (von Hippel, 2005) that involves meaningful engagement with users and stakeholders. The wicked problems in the health sector are typically unique, requiring unique creative solutions that are built

from the ground up *with*, rather than *for*, the people who will use and benefit from them. As mentioned in the Introduction, the three pillars of this approach are:

- Transdisciplinary working.
- Coproduction.
- Effective outreach.

We do not claim that this book will guarantee success in creating practical solutions and impact, but the aim is certainly to try to increase the likelihood of this happening.

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Further Reading

For some excellent examples of healthcare innovation, see Morgan, B. (2019). Healthcare innovation—10 recent examples of powerful innovation in healthcare. Forbes.com. https://www.forbes.com/sites/blakemorgan/2019/03/12/healthcare-innovation-10-recent-examples-of-powerful-innovation-in-healthcare/#684d760757dc.

Chapter 3
Understanding the Product Innovation Pathway

Andrew Sixsmith, Judith Sixsmith, Mei Lan Fang, and Alex Mihailidis

In Chap. 1, we introduced the key idea of *engaged* research. In the later *how-to* sections of this book, we look at some of the practical actions we can take to implement these ideas in real-world research. Before we do that, we need to introduce two further organizing ideas that underpin this book:

- Products: The idea of research *products*—the technologies, services, toolkits, and policies that will be produced through our research and implemented and used in the "real world." Traditionally, the main outputs of academic research are ideas, concepts, theories, and empirical evidence that are disseminated in journal articles, books, and conference presentations. These are important but often fail to have a direct impact on potential beneficiaries. If we are to be serious about real-world innovation, the research outputs need to be *packaged* in a way that means they can be readily adopted by the people who will use them, i.e., the end users, patients, customers, and service providers.
- The Product Innovation Pathway (PIP) model: PIP represents different levels of product maturity—the process of moving from initial ideas toward deployment, mobilization, and adoption of a product.

These ideas are followed up in the *how-to* chapters, where we look at the different kinds of activities that a research team should be engaging at different stages in the innovation process.

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What Is a "Product"?

The first key idea is that research projects that aim to address social problems should produce tangible *products* that will have social and economic impact, that is, they should make a positive difference in people's lives. Progress toward these products can be defined and tracked across different levels of maturity as they move from basic research to implementation and deployment. It is important to make a distinction between research *outputs* and *products*. An output is anything created by a project during its research and innovation activities. These may include scientific papers, prototypes, patents, business plans, evaluation reports, etc. In contrast, a product is what the project is aiming to deliver as its ultimate end output that will be utilized in the real world. Products are tangible and require the research team to think in concrete terms:

- *What* does the product look like?
- *Who* is going to use it?
- *When*/*Where* is it going to be used?
- *How* is it going to get to its intended audience or market?
- *Why* would someone adopt and/or buy it (i.e., what is its value proposition)?

While this *productization* is typically addressed after the research phase in a project (if it is addressed at all), we propose that this process needs to begin right at the start of a project. For example, trying to visualize what the final product will look like will help research teams to identify the kinds of expertise needed to ensure the development of such products are an integrated part of the research process and to make decisions early on that will help to avoid problems that may be encountered later in the innovation process.

While the idea of innovation often implies new technologies, the *products* from research projects are typically wide ranging, for example:

- Technology products: These are the interventions, systems, and devices aimed at directly supporting the health of patients and consumers. Note that these may include new drugs or surgical procedures. They are, however, outside the scope of our book.
- Service products: These are the delivery models and mechanisms that will allow new technologies, solutions, etc. to be provided to the user or patient.
- Knowledge products: These are about the provision of information. They include policy briefs, guidelines, standards and regulations, models of good practice, as well as health-related information for the public.

Figure 3.1 provides a diagram of the Canadian AGE-WELL NCE (Aging Gracefully across Environments using Technology to Support Wellness, Engagement and Long Life Network of Centres of Excellence) definition of the outputs of its research projects. Innovation research works toward developing at least one of three products and, of course, a project may create several products that fit into one or more of the product types. Indeed, it might be crucial for a project to develop

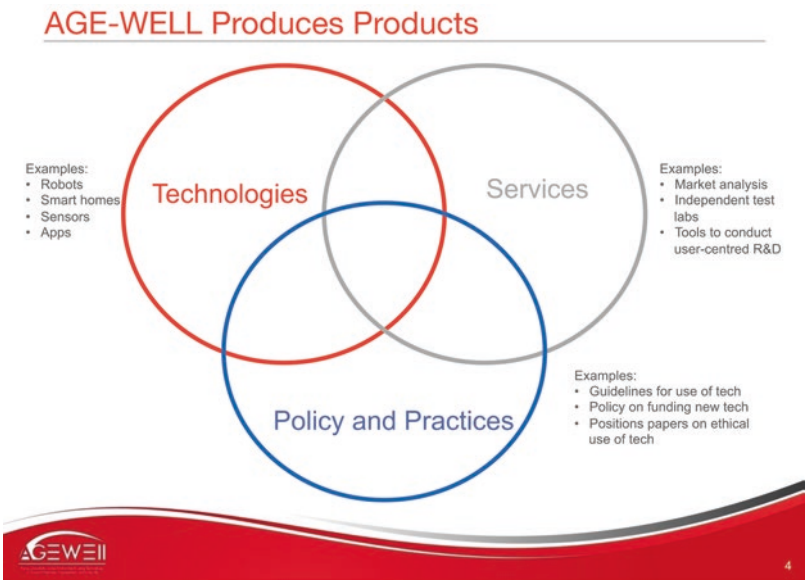

Fig. 3.1 Types of Products

multiple products in order to achieve real-world impacts. For example, if a technology is to be adopted, this may require the implementation of policy, provision of information to the users, or training on how to use or implement it.

While the idea of a product is intuitively connected to technologies, it is important that other types of products are defined in similar terms. Knowledge outputs from scientific research tend to be produced for academic audiences and so are quite inaccessible for use by lay audiences or product users, although the call for more accessible research products is becoming a more common requirement of research funders. Crucially, *products* need to be in a form that can be readily adopted by the people who will use them. However, researchers often have not developed the skills or the motivation to ensure that their products reach or are implemented by the intended user. The intention of this book is to support researchers in appreciating and developing these kinds of skills.

Visualizing Innovation: The Product Innovation Pathway (PIP)

The way products move from initial concept to final implementation is the second key idea in this chapter. This is particularly an issue to consider in relation to research and development of new technologies. Advancing innovation requires mechanisms that effectively manage and assess the risks of technology development

through to its maturation into the market. There are a number of approaches available that serve this purpose. One approach to assess product maturation (i.e., usability, feasibility, and sustainability) that has become extensively used is the National Aeronautics and Space Administration's (NASA) *technology readiness levels (TRL)* (Mankins, 2009). The TRL scale encompasses nine levels of maturity with level one concerning the development of ideas and level nine indicative of technology in its most mature form (Fig. 3.2).

The use of TRL enables consistent, uniform mapping of maturity across different types of technology. The TRL approach has strong roots in the engineering field but is starting to be used elsewhere. For example, Canadian Institutes of Health Research (CIHR) use a simplified version of the TRL in their eHealth program (http://www.cihr-irsc.gc.ca/e/48614.html).

The TRL scale has been adapted in this book to create a more generic and inclusive Product Innovation Pathway model recognizing that there are a number of issues that make the TRL model less than ideal for use outside the field of engineering:

- The nine-point TRL model is primarily aimed at tracking and managing progress of a project as it has a high granularity that is important for evaluation but is less relevant to education and capacity building, where the aim is to increase insight and understanding and where a simpler model is more useful.
- There is quite a lot of overlap of different levels in the model in terms of actual activities that might be being carried out. For example, technology development might be a very iterative process in reality.
- TRL focuses on technology development and does not encompass other areas of project activity, such as commercialization activities.
- The TRL levels focus on technologies, and it is less appropriate for non-technology products such as services, policies, and practice. For example, TRL 4 "laboratory validation" is not appropriate for non-technology products.
- The TRL levels give the impression that innovation is a straightforward linear process, while the reality may be much more circuitous and reflexive, requiring

PIP Level	Description
TRL1	Basic principles and research data observed and reported.
TRL2	Technology concept and/or practical application formulated.
TRL3	Analytical and experimental proof of concept of critical function and/or characteristics.
TRL4	Validation of the technology in the laboratory.
TRL5	Validation of technology in a relevant environment.
TRL6	Demonstration of technology in relevant environment.
TRL7	Technology prototype demonstrated in an operating environment.
TRL8	Technology system completed and qualified through test and demonstration.
TRL9	Technology system in its final form ready for full (commercial) deployment.

Fig. 3.2 Technology readiness levels (general definitions)

a more iterative process. This means that in the PIP model, end results should be evaluated by attainments that, for example, benefit end users and the wider community, which influence policy and quality of life rather than defining "success" only by financial gains.

The Product Innovation Pathway Model

In this book, we argue that the innovation process across different product types is broadly similar, and we have adapted the different technology readiness levels to create a simpler and more inclusive model of health innovation and product maturity. We have called this the Product Innovation Pathway (PIP) model (Table 3.1). There could be many ways of representing the PIP. Our model is meant to be simple and generalizable across different types of research projects and products. The key aim of this book is to provide a consistent and simple framework that will be used in all the following *how-to* chapters.

- Level 1: Innovative ideas. All research projects and potential products have to start with ideas. A major theme in this book is that researcher or technology-driven solutions are likely to fail and that co-creation and collaborative approaches are more likely to result in something that is useful. To start with, this could be a problem or a need that someone has identified such as a service provider who wants to make her or his services more accessible to patients or users. It could be an idea that is based on some new discovery that has been made in a lab. It could be the application of some well-established idea from one sector to another, such as everyday technologies that have trickled down from space program research.
- Level 2: Planning. Rather than *incubation*, which seems to point to a hot housing of ideas and research activity by researchers themselves, and separated from real-world contexts, the new title of *planning* refers to a much broader process or set of activities that can include input from a range of nonacademic stakeholders. For example, the research and development of technologies to improve the health and well-being of older adults might involve healthcare professionals, industrial partners, older adults, and carers that locate the research firmly in the everyday contexts in which the technologies will be used. As such, rather than incubation with its implication of separation and spontaneous growth, the notion of planning is very much seen as an iterative, inclusive, and participatory process.

Table 3.1 Product Innovation Pathway levels (general definitions)

PIP level	Description
PIP1	Generating innovative ideas
PIP2	Planning the project
PIP3	Developing the product
PIP4	Testing in real-world settings
PIP5	Creating outcomes and impact

- Level 3: Development. A key step in this process is the development of the tangible product itself. This may include prototypes of a specific technology, such as robot or sensor, of drafts of new practices, policies, and guidelines. The approaches used in the development phase will differ based on the type of product being developed (and is outside of the scope of this book), but the common feature is that product development is an iterative process that involves the development of multiple prototypes, drafts, etc. This iterative development process should be driven by constant input and feedback from key stakeholders, such as end users of the intended product.
- Level 4: Testing in real-world settings. New ideas, models, findings, and prototypes need to be tried out in real-world settings—in situations that approach the real-world context in which it is going to be used. In some areas, this kind of testing has very rigorous and well-established protocols. For example, in the development of new drugs, these have to be tested in randomized, clinical trials with real patients to determine the efficacy and potential side effects. In other types of research, this kind of testing is not always feasible. For example, buildings cannot usually be tested prior to their construction, so post-occupancy evaluation is used to provide information for future projects. Complex interventions such as new technologies or services are typically piloted with potential end users, but often the scale of the research is limited by practical considerations. However, the key objective here is to provide strong evidence about that usability, feasibility, and sustainability of a product. This will provide essential information about how the product needs to be adapted or commercialized. Evidence from trials and product testing will help to convince potential users and consumers to adopt or purchase the product.
- Level 5: Outcomes and impact. Research needs to go beyond the normal academic boundaries in order to ensure real-world impact. The *products* of a project—a technology, policy, and/or practice or service—need to get into the hands of the people or groups who will benefit from them. It is not enough to assume that good ideas will be automatically adopted. Typically, these *knowledge translation* activities are put at the end of a project. In this book, we argue that this needs to be at all levels of the PIP model. However, it is clear that many of the practical and commercial steps required to get products adopted will occur at this stage.

These different levels constitute an important organizing idea that recurs in many of the chapters in this book. Specifically, the book's *how-to* chapters provide examples and suggestions about the kinds of activities a project might engage in at different levels in the model. These are not meant as a set of blueprints but are offered as suggestions and examples of the kinds of activities that might be needed at different steps in a project.

Progressing Through the PIP Levels

It is very important that the PIP model is viewed as a framework rather than a simple linear set of steps through which a project progresses. Innovation is rarely straightforward, and there could be many different pathways through the innovation process:

- The pace and direction of movement through the different levels will vary from project to project, depending on factors such as technical challenges.
- Progress is nonlinear, and iterative projects work toward implementation, but this might not always be in one direction.
- These are levels and not stages: this isn't a blueprint, and project teams need to work creatively to progress.

However, a key point is that all projects have a start, a middle, and an end. In particular, the end point that we emphasize in this book concerns the production of a product placed in the hands of people who will benefit from it. It is this *end point* that the current book is aimed at, i.e., helping researchers to better visualize and plan toward delivering their product to people who need it.

Many of the activities that are typically thought of as happening in an end phase of knowledge translation or commercialization need to be thought about much earlier in a project if they are to have more chance of success down the line. The *how-to* chapters in this book deal with different project activities to help research achieve direct social and/or economic impacts. Accordingly, each of these chapters contain guidelines that show the sorts of activities researchers might consider carrying out at the different PIP levels to create products that have tangible benefits.

Key Messages

- Projects are expected to create one or more tangible real-world products.
- Products can be of three main types: technologies, policies and practice, and services.
- Product innovation is characterized by five levels of maturity from early ideas to real-world implementation.
- Projects can progress though these levels in different ways—we call this the Product Innovation Pathway model.
- Later chapters in this book look at the different kinds of project activities at different levels in the PIP model.

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