1. Translating Smart Kitchen technologies from the lab to the home

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INTRODUCTION

With changes in federal law regarding ownership of university-developed innovations, university-industry technology transfer is seen as a means to accelerate the commercialization of newly developed university technologies and promote economic development and entrepreneurial activity (Siegel et al., 2004). Many university-developed advanced technology innovations, including those focused on improving the quality of life for their users, move from research and development, usability studies and clinical research into various stages of commercialization (Seelman, 2013). However, this transition often requires surmounting many challenges and barriers to successful commercialization and widespread adoption (Anokhin et al., 2011; Ball and Preston, 2014; Borisoff, 2010; Martin, 2007; Miller and Acs, 2013; Nath et al., 2013; Sheth and Ram, 1987; Seelman, 2013).

Successful technology transfer can have measurable benefits for the universities and their innovators. McDevitt et al. (2014) reported $2.6 billion total income received by reporting universities. In addition to these revenue generation results, other benefits from technology transfer noted in this study include increased opportunities for funding as a result of technology transfer programs, promotion of a culture of entrepreneurship and innovation, increased student success, public benefits through both universities meeting their public missions and improved quality of life, and economic development. Economic development results reported were $36.8 billion of net product sales generated, with start-up companies related to innovations from 70 academic institutions providing work for almost 16 000 full-time employees. They also report increases in licensing, start-ups and cumulative active licenses, with over 40 000 cumulative active licenses, 5145 issued US patents, 6372 new licenses and options executed and 705 new start-up companies formed.

Regarding student success, Martin et al. (2013), in their recent quantitative review of the entrepreneurship education literature, found significant relationships between entrepreneurship education, training and entrepreneurship-related human capital assets, and entrepreneurship outcomes, with academic-oriented education having a stronger relationship than training. Thus, entrepreneurship education has been shown to enhance relevant knowledge and skills, as well as result in positive outcomes. Focusing more specifically on innovation and commercialization of university-developed technologies, several approaches have been applied. Incubators and proof of concept centers have been developed to move technology out of the university (Gulbranson and Audretsch, 2008; O'Neal, 2005; Phan et al., 2005). One such example in the biomedical space is Washington University's IDEA (Innovation, Design, and Engineering in Action) Lab, which is a biomedical design and entrepreneurship incubator (Som et al., 2014). Fostering start-ups are another pathway for commercialization of university technologies (Swamidass, 2013).

Universities have explored education-based initiatives. Numerous schools have implemented Bench to Bedside initiatives to bring technology into use, often involving students in these projects. Johns Hopkins has implemented a two-semester graduate course sequence known as 'Discovery to Market' that provides both instruction in technology transfer and commercialization and a hands-on project (Phan, 2014).

The purpose of this chapter is to report the results of a service-learning project designed to explore potential technology transfer pathways for a suite of assistive technologies – the Smart Kitchen (Ding et al., 2014; Mahajan et al., 2013; Telson et al., 2013; Wang et al., 2013; Yiin, 2014). The Smart Kitchen is being developed by the Human Engineering Research Laboratories (HERL). Our approach was guided by existing models of technology transfer (Anokhin et al., 2011; Siegel et al., 2004), as well as by processes of quality of life technologies (QoLT) development (Schulz et al., 2012). We ask the question: What are the potential pathways to successful commercialization of the Smart Kitchen innovations? In order to address this question, we explore the related questions of (a) are the potential pathways identical for all three components of the Smart Kitchen?; (b) are the potential pathways identical for all target user populations?; and (c) what resources and capabilities are necessary to innovate and commercialize the Smart Kitchen?

QoLT are designed to impact the quality of life of individuals who use them (Schulz et al., 2012). Most people want to live in the settings that they are accustomed to for as long as they can (Seelman et al., 2007). In recent years, research has focused on technologies that can assist in achieving this goal of independence for individuals with, or at risk of, impaired functioning due to trauma, chronic disorders or aging (Schulz, 2013; Schulz et al., 2012). These QoLT are intelligent systems and devices responding to the unique needs of older adults and persons with disabilities (Seelman et al., 2007). In a study using a nationally representative sample of US baby boomers (aged 45–64) and older adults (aged 65 and up), most of these individuals were willing to pay for help with kitchen or personal care activities (Schulz et al., 2014). However, this study noted that, based upon the amounts individuals were willing to pay and the third-party payer models in place (Medicare and insurance), these technologies would have to be cost-effective to gain market and payer acceptance. To accomplish this, these QoLT must successfully move from the laboratories into the marketplace and into the home, where they can provide assistance to those who need it and relief for caregivers, at costs that are within the willingness to pay of both users and payers.

Technology transition of assistive technologies for people with disabilities has been an area of active focus for some time. A decade ago, Lane (2003, p. 334) summarized existing technology transfer work within this field. He described technology transition as ‘a value-added process that encompasses a continuum of related activities from laboratory innovation through market consumption.’ Along this continuum there also exist a number of policy and regulatory tensions – tensions caused by technologies radically different from those envisioned when regulations were established, as well as tensions relating to financial considerations and healthcare cost and reimbursement guidelines (National Council on Disability, 2000; Seelman, 2013).

As Bauer (2003, p. 285) described the situation,

> Technology transfer has generally had little impact on the assistive technology industries serving small highly fragmented ‘disability markets.’ Persons with disabilities often require specialized, relatively sophisticated technology.

> Third-party payer reimbursement rates and the low levels of disposable income among disability populations often cap product pricing. Transferring technology to these industry segments therefore poses special challenges.

This challenge is one that clearly highlights these tensions. Bauer (2003) points out the concern regarding third-party payer reimbursement rates, while more recently Schulz et al. (2014) point out user willingness to pay some amounts for these technologies, but the overcaution that these technologies must be cost-effective because of these third-party payer pressures. Wagner and Bremer (2001, p. S49) also note an additional challenge to the commercialization and use of certain technologies. QoLT or assistive technologies that are not medically necessary are often not covered by Medicare, Medicaid or insurance programs, thus potentially hindering the introduction and uptake of these new technologies.

Nonetheless, multiple laboratories are addressing the needs of these 'disability markets' by addressing QoLT. However, it has been claimed that invention is not the great challenge in reaching these populations, but rather that the 'bottleneck comes in the transfer of the technology into the commercial sector' (Wagner and Bremer, 2001). As Leahy (2003, p. 305) pointed out, 'many useful products are already invented, but they are not available to consumers, because the inventors lack resources to move the invention to the marketplace.'

Numerous previous studies have examined technology transfer of assistive technologies (for example, Bauer, 2003; Borisoff, 2010; Lane, 2003; Leahy, 2003; Schulz and Beach, 2013; Seelman, 2013; Stone, 2003; Wagner and Bremer, 2001). Other studies have examined assistive technology development efforts as service learning (Goldberg and Pearlman, 2013; Livingston, 2010).

One of the challenges highlighted by Wagner and Bremer (2001) is a need to understand which technology transfer practices will work in differing situations, with different types of technologies or for different markets. Commercialization pathways could include intellectual property protection through patents, retaining ownership of an innovation and bringing the innovation to market, sharing the innovation through licensing it or developing (or co-developing) it with partners or by selling the innovation (Datta et al., 2012; Webster and Jensen, 2011).

A technique that can be applied to address these differences in situations, technologies and target populations, capturing possible technology transfer pathways to commercialization and use is Technology Roadmapping (TRM). TRM is a strategic decision process framework that supports enterprise innovation activities, has attracted the interest of an increasing number of academics and practitioners and has been applied in many different industrial sectors and organizations (Carvalho et al., 2013; Lee and Park, 2005; Lee et al., 2011; Moehrle et al., 2013; Phaal et al., 2004; Phaal et al., 2010; Vatananan and Gerdsri, 2012). The technique originated at Motorola (Richey and Grinnell, 2004; Willyard and McCless, 1987). It is flexible and customizable to fit the strategic context in which it is being applied (Lee and Park, 2005; Phaal et al., 2004; Vatananan and Gerdsri, 2012).

Roadmaps are often used to link technologies to strategic goals and future market opportunities (Fenwick et al., 2009; Probert et al., 2003). In this way, TRM can serve to help principal investigators plan their activities as boundary spanners (Mangematin et al., 2014), helping to design pathways to market opportunities. For example, Chang (2010) identifies a series of internal capabilities and environmental drivers that can explain e-business adoption through the proposed roadmap.

Zurcher and Kostoff (1997) applied TRM to the development of fuel-efficient non-polluting cars. Recent applications include sustainable information technology (Harmon et al., 2012), services, devices and technologies for Smart Cities development (Lee et al., 2011), e-business adoption (Chang, 2010) and Internet security technology (Fenwick et al., 2009).

A technology roadmap is often represented using a multi-layer graphical representation of a plan that connects technology and products with market opportunities (Carvalho et al., 2013; Probert et al., 2003). Figure 1.1 depicts the technology roadmap format depicting a multi-layer, time-based chart that links resources and competencies, the technology

	Short Term	Long Term	Layer Time horizons
External Driver *Internal*			Purpose
Channels			Delivery- mechanisms
Product			Products
Technology			Technology
Resources			Resources/ Competencies & Skills

Source: Adapted from Carvalho et al. (2013), Wells et al. (2004) and Probert et al. (2003).

Figure 1.1 Technology roadmap format

and its development and market drivers. It introduces the concept of market channels to explore means of linking the technology under development with the targeted populations.

THE SERVICE-LEARNING PROJECT

The service-learning project (Decker, 2000; Tsang, 2000) was a key component of the Fall 2013 Leadership in the Social Environment (LSE) course. This course is an integral part of the Certificate Program in Leadership and Ethics (CPLE) in the College of Business Administration at the University of Pittsburgh.

Project Participants

The service-learning project was a collaborative effort between the CPLE Class of 2015, faculty and students from HERL and technology transfer experts from Pitt's Innovation Institute, the university's technology transfer office.

While team-based design courses focused on products for people with disabilities have become relatively common, often supported by training grants such as the National Science Foundation's Research to Aid Persons with Disabilities course grants (Goldberg and Pearlman, 2013), this course was significantly different, as it involved business students and focused on commercialization, rather than development, of assistive technologies.

CPLE Undergraduate Team

The CPLE team consisted of the 20 undergraduate students of the CPLE Class of 2015. Our CPLE initiative is the only program across the country that offers undergraduate business students an integrated and sustained program of study into the relationship between leadership and ethics. It contributes to a student's preparation for a career in business by providing hands-on experience into the complex nature of ethical leadership in today's business environment. The CPLE is designed to strengthen the Bachelor of Science in Business Administration (BSBA) program. Thus, students pursuing the CPLE must also be enrolled within the College of Business Administration.

This program is a unique opportunity for undergraduate business students who wish to explore the relationship between leadership and ethics. It contributes to the student's preparation for a career in business by helping to foster contacts with organizations committed to leadership and ethics. The CPLE curriculum is based on the belief that students ought to experience a sustained and integrated exposure to ethics and leadership in organizations. It is also based on the assumption that an emphasis on leadership, without proper consideration of ethics, will not generate leaders who approach their roles with a sense of responsibility and accountability; while an emphasis on ethics, without proper consideration of leadership, will not produce leaders with the necessary tools to develop and implement their vision and understanding of ethics. Thus, leadership and ethics must be considered together. Courses within the CPLE curriculum focus on the development of five key competencies areas: ethical awareness and decision-making; relational leadership; high impact communication; team project management; and civic/social engagement.

Human Engineering Research Laboratories (HERL)

HERL is a collaboration between the University of Pittsburgh, the VA Pittsburgh Healthcare System and UPMC Health System. HERL is dedicated to wheelchair and mobility research, specifically by improving the mobility and function of people with disabilities through advanced engineering in clinical research and medical rehabilitation. HERL also studies athletics in rehabilitation, assistive living spaces, the efficiency of wheelchair transfers, clinician training and force and vibration on wheelchair users. HERL is affiliated with the QoLT Center, a National Science Foundation Engineering Research Center for Quality of Life Technologies. The QoLT Center is a unique partnership between Carnegie Mellon and the University of Pittsburgh that brings together a cross-disciplinary team of technologists, clinicians, industry partners, end users and other stakeholders to create revolutionary technologies that will improve and sustain the quality of life for all people. The QoLT Education and Outreach mission is to create a growing community of engineers, scientists, practitioners and consumers who are intellectually prepared and motivated to create and apply technology to benefit people with disabilities and older adults.

Innovation Institute

The mission of the Innovation Institute is to facilitate the translation of research into innovations and start-ups that have impact. It has emphases on commercialization, entrepreneurship and economic development. Licenses and options, patents and support for start-ups are key activities, as well as a variety of training programs and innovation events.

Project Purpose

This project involved an analysis of technology commercialization options for a set of technologies that HERL is continuing to develop. As the class undertook the project to assist HERL, their primary focus was on analysing technology commercialization options for the Smart Kitchen. This focus was not just on developing a simple marketing plan for the Smart Kitchen technologies, but explored multiple pathways to commercialization, tailored to different populations; developed proposed approaches to pathways to commercialization and licensing of these emerging technologies; and addressed the issues and needs of business and policy ecosystems affecting these multiple populations.

The service-learning project embedded within this course engaged students through professional activism (Decker, 2000), linking students with community needs. In this case, the linkage was multi-level, as one level was linking students with their client at HERL, but also linking them with stakeholders, in this case, a large potential user population and their needs. It has been argued that participation in service-learning projects that benefit a larger community can substantially enhance student learning, support life skill development, increase a sense of civic responsibility and provide a foundation for future professional practice aware of professional, social and civic responsibilities (Tsang, 2000).

The CPLE competency of civic/social engagement is evidenced in a number of substantial, measureable impacts of the CPLE curriculum. These include a positive impact on the local community, primarily through the efforts of students who have worked with local business owners and leaders, have provided opportunities and opinions for local businesses and helped to improve local business and non-profits at no financial cost to the organization. In this project, our community focus was on HERL and potential commercialization partners.

Possible recipients of the social impacts of this course could go far beyond local businesses. Beneficiaries of the outputs from this course could include the target populations of potential users of the Smart Kitchen. Second, the university and its technology transfer units could benefit, as the university has approximately $700 million in funded research (University of Pittsburgh, 2014), and the results of this project may help other projects plan for commercializing their research. Results could also potentially be useful to funding agencies, especially with increasing emphases on industry-university collaborations and commercialization of research. Lastly, this research could have an indirect impact on taxpayers, seeing federally funded research put to work in addressing target populations and potentially lowering caregiving costs in these populations.

The project addresses a critical need as identified by our research partner. This project represents an important experiential exercise that will lead students to develop an understanding of the subtle connections between the role of the individual leader and an organization and its social environment. Students were introduced to concepts of technology transfer via lectures and interaction with experts from the Innovation Institute, licensing via lecture and technology roadmaps through lecture and a hands-on workshop.

On completion of the course and its service-learning project, students accomplished the following:

- Developed an understanding of macro-level concepts related to corporate social responsibility (CSR) and corporate social performance (CSP) as a leadership model for managing the relationship between organizations and society. Students applied CSR/CSP concepts in examining potential participants in the technology commercialization pathways, and explored the relationships between these potential participants and the target populations.
- Participated in a team case presentation to a client, in which student teams were charged with applying course concepts to a case problem relevant to their client, HERL. At the conclusion of the course, students made a presentation to their client, responded to questions and delivered a 129-page report to the client (Certificate Program in Leadership and Ethics Class of 2015, 2013).
- Developed an ability to apply the concepts of CSR by completing a community impact project that included recommendations concerning CSR within a contemporary business context. These recommendations were embedded in the body of the report prepared by students.
- Enhanced their project management skills by working in one or more small teams as part of a larger class project. Students were divided into teams, with each team focusing on a distinct potential user population of the Smart Kitchen and one team performing an overall coordination and planning role. This allowed for collaboration across teams and coordination of activities among teams to produce an integrated final report and presentation.

These activities provided a model for engaging business students in translational research commercialization, applying a cross-disciplinary approach, serving a role as translator, bridging business concepts for the HERL research team. Their efforts clearly met the CPLE raison d'être – students ought to experience meaningful and experience-based exposure to ethics and leadership in different organizational settings. The technology of the Smart Kitchen, its potential user populations and the possible commercialization pathways to bring this technology to the market in order to be useful to these populations provide a rich view into multiple organizational settings for project participants. The next section introduces the suite of Smart Kitchen technologies.

THE SMART KITCHEN

The 'Smart Kitchen' is a suite of technologies being created by HERL (Ding et al., 2014; Mahajan et al., 2013; Telson et al., 2013; Wang et al., 2013; Yiin, 2014). A key attribute of the Smart Kitchen is incorporating prompts to assist users with activities of daily living (ADL) (Wang et al., 2013). This is one example of technologies encompassed by the broader concept of a Smart Home – a home that utilizes sensing technology and networking infrastructure with intelligent software to enhance the quality of life of those living in the house (Augusto, 2012).

There are a number of issues driving the development of the Smart Kitchen. These include a growing population of older adults and people with disabling conditions, with 11 million needing personal assistance with everyday activities. Caregiver issues include a caregiver shortage and burden, a growing gap between caregiver supply and demand and caregiver demands outside the home – 25 percent of families care for someone outside the home and one third of nursing home admissions are due to caregiver burnout. Increasing costs are also drivers: both soaring homecare costs borne by families and third-party payers and increasing costs of institutional care, where a one-month delay in Alzheimer's disease and dementia nursing home admissions could save $1.12 billion annually (US Census; Graham, 2014; Johnson et al., 2000; National Center on Caregiving, 2005; Smialek, 2013; Stone and Wiener, 2001; Zywiak, 2013). As these savings indicate, if the Smart Kitchen technologies prove to be effective in keeping residents safe in their home environments and away from nursing homes, that would save insurance costs for a comparatively lesser preliminary investment in technology infrastructure and support (Chan et al., 2008).

The three technologies comprising the Smart Kitchen are the Cueing Kitchen, KitchenBot and the Interactive Display. These technologies can be deployed as an integrated Smart Kitchen, or could potentially be deployed separately. Having these options allows the end user (or caregivers) to pick and choose which pieces will work best for them and ultimately make it a more effective product. When the 'Smart Kitchen' is referred to in this chapter, the entire suite of technologies described below is being referenced.

Cueing Kitchen

The Cueing Kitchen is a cognitive orthosis with advanced sensing and prompting tools designed to satisfy needs that individuals, such as people with traumatic brain injury (TBI), face in their activities around their kitchen, specifically focusing on meal preparation tasks (Mahajan et al., 2013). The Cueing Kitchen is comprised of sensors and lights, which are activated by a unique software program. When the software prompts for a certain item in the kitchen, the sensors and lights become activated in order to assist the user. The lights are attached to the handles and light up to show that something is located within the cabinet. The sensors are used in order to judge whether something is not closed or turned off properly. The sensors also help to control the switch for water, the oven and stove, along with the refrigerator door. In addition, the normally frosted glass cabinet doors can become transparent to provide additional locational cues to users.

KitchenBot

The KitchenBot design incorporates an overhead mounting system for a dynamic robotic manipulator to assist individuals with physical disabilities in tasks associated within a kitchen environment. The KitchenBot has three main components. First, a wall mounted track allows the KitchenBot to move along the cabinets. Second, a vertical column drives horizontally, guided along the track. Third, a commercially available six-degree of freedom robotic manipulator mounts to the vertical column (Telson et al., 2013). The KitchenBot uses this mechanical arm to lift items up and move them from point A to point B. This arm works with the Cueing Kitchen to open up cabinet doors, turn on and off the faucet and to pick up and to place down items. The arm can be controlled two different ways: with a joystick or through voice activation.

Interactive Display

The Interactive Display is a hologram that is reflected onto a surface. This display is able to detect certain objects to assist with the compiling of ingredients for recipes. The display works with the software that is used for the Cueing Kitchen, which makes it very easy to go from start to finish when making a recipe.

For purposes of examining potential technology transition of these technologies, each of the three technologies can be transitioned together or separately. Having these options allows the commercial developer or perhaps even the end user to pick and choose which pieces will work best for them and ultimately make it a more effective product.

METHODS

Analyses of Target Populations

This study examined the potential for moving these technologies into use by four populations, each of which are described in the following paragraphs. The three primary target populations explored were Wounded Warriors and individuals with TBI, individuals with physical disabilities and aging individuals (65+). As justified below, the analyses also considered a potential mass market user population.

Wounded Warrior/Traumatic Brain Injury

Wounded Warriors (WW) are veterans and service members who incurred a physical or mental injury, illness or wound, co-incident to their military service on or after September 11, 2001. Individuals with TBI are those who have a severe brain injury. The number of veterans returning from Operation Enduring Freedom (OEF), Operation Iraqi Freedom (OIF) and Operation New Dawn (OND) with TBIs was 253,330, while 1,715 veterans of the same campaigns experienced amputations (Bauer, 2013). Approximately 1.7 million people in the United States sustain a TBI each year from all sources (Faul et al., 2010). The current estimated number of TBIs in the United States is 3.2 million people, with 43.3 percent having residual disability one year after hospitalization with TBI.

TBIs are caused by a diverse range of events and are typically classified as mild or severe. Depending on the severity of an injury, an individual's cognitive behavior, speech, sensory and perceptual senses can all be affected. Various cognitive deficits such as problems with memory, attention, planning and executive functions affect individuals who have experienced TBI (Sohlberg and Mateer, 2001). These cognitive deficits can have an impact on an individual's completion of ADL independently.

While ADL are basic self-care tasks, instrumental activities of daily living (IADL) are those complex skills needed to successfully live independently. Cooking tasks have been identified among ADLs as essential skills for living independently (Graves et al., 2005; Horsfall and Maggs, 1986; Mechling, 2008). Individuals with TBI may encounter difficulties in independently completing certain IADL, such as meal preparation, due to problems with attention, cognition, memory and executive functions (Mahajan et al., 2013). They also report a number of kitchen activities, ranging from following recipes to appropriately turning appliances off, as a source of stress (Mahajan et al., 2013). Remembering the location of items and keeping track of recipe steps are the two most difficult activities for adults with TBI in performing kitchen tasks (Wang et al., 2013).

Physically disabled

People with physical disabilities have physical impairment that have substantial and long-term effects on their ability to carry out day-to-day activities. The physically disabled population considered in this study range from ages 18–65. Physically disabled individuals deal with impairments such as 'any physiological disorder or condition, cosmetic disfigurement, or anatomical loss affecting one or more of the following body systems: neurological, musculoskeletal, special sense organs, respiratory (including speech organs), cardiovascular, reproductive, digestive, genitourinary, hemic and lymphatic, skin, and endocrine' (Title 28 CFR 35, 1991). In 2012, adults with disabilities comprised 19,650,900 out of 194,611,800, or an estimated 10.1 percent, of working age Americans (ages 18–64) (Cornell, 2012).

The ability to adequately reach for objects impacts ADL (Holliday et al., 2005). Such functional limitations, which are required for interacting within a kitchen environment, can be caused by the natural progression of a medical condition, such as a physical disability, as well as by other causes such as aging or trauma. Individuals with limited or no upper limb ability have identified the kitchen as a desirable site for accommodating an assistive robotic device (Stanger et al., 1994). Kitchen tasks that have been identified by potential users as those where they require at least frequent assistance were moving hot objects from the stove, moving hot objects from the oven, putting in/taking out heavy objects, carrying heavy objects, stabilizing pots on the stove and opening/closing/reaching a cabinet above the countertop (Ding et al., 2014).

Aging

Kohlbacher and Herstatt (2008) have identified demographic shifts, in both aging and shrinking populations in many countries, as a major societal challenge. By 2050, the aged population (older than 65 years) in the United States is projected to be over 88 million Americans, more than double the aged population in 2010 (Vincent and Velkoff, 2010). While many consider the so-called 'silver market' to be those age 50 and over, this study limited its focus to an aging and elderly population that includes individuals aged 65 and above. These individuals are more vulnerable to be affected by dementia, Alzheimer's and physical disabilities. Additionally, over the next 15 years the aging and elderly populations are anticipated to increase by 6 percent in the make-up of the American population. Of this aging population, in 2012, an estimated 35.8 percent (14,966,400 out of 41 823 600) of Americans aged 65 and over reported a disability (Cornell, 2012). The caregiver shortage and desires for continued independence in ADL also impact the aging population.

Kohlbacher and Hang (2011, p. 88) identified the aging population as being likely to adopt innovations that 'target non-consumption and help to support and enrich elder people's lives and work.' In a study of user preferences of baby boomers and older adults regarding technology versus human assistance and control over such technology in the performance of kitchen and personal care tasks, Beach et al. (2014) found that these populations may indeed be potentially receptive markets for the adoption of QoLT systems.

The Smart Kitchen is such an innovation. Other researchers have explored similar innovations for this population, for example, Pigot et al. (2008) examined recipe assistance for an aging population. These innovations may be useful to this population, as about one in ten adults aged 55 years and over have difficulty reaching (11 percent) or grasping (9.4 percent), with these rates tripling between the ages of 55–64 years and 85 years and over (Schoenborn and Heyman, 2009).

Mass market

In addition, the analyses also examined transition of the Smart Kitchen technologies to the mass market, as it was considered that broader adoption of these technologies may provide commercialization incentives that could have spill-over effects for the primary target populations, especially as Bauer (2003, p. 285) noted the difficulties in technology transfer to 'small, highly fragmented "disability markets."' Because the purchase price of many assistive technology products (for example, the Smart Kitchen suite) is strongly influenced by third-party reimbursement policy (for example, Medicare, Medicaid, private insurance) and the legislations that shape these policies, rather than by competitive market forces (Bauer, 2003; Seelman, 2013), the CPLE project team also studied a fourth potential population – the mass market.

ANALYSES

The students undertook an analysis of the commercialization prospects of HERL's Smart Kitchen and its components to identify possible technology roadmaps and pathways to bring the Smart Kitchen technologies to market. For each of the four target populations, barriers and market drivers were identified (Nath et al., 2013), a long-term technology roadmap was developed, an implementation plan was proposed, financial needs for these implementation plans were estimated and Strengths, Weaknesses, Opportunities and Threats (SWOT) analyses were conducted to address the strategic positioning of HERL to address the needs of the target population. Further, a proposed plan for HERL's next steps was developed for each population.

Prior to developing their roadmaps, students undertook a technology roadmap workshop, and were provided with access to background materials (for example, Garcia and Bray, 1997). Five technology roadmaps were developed, with four of the five roadmaps unique to each population that was analysed (Wounded Warrior/Traumatic Brain Injury, Physically Disabled, Aging and Mass Market). The fifth roadmap is a coordinated roadmap, which serves the purpose of combining and emphasizing common or similar points amongst all of the four populations.

Each technology roadmap organizes various categories of information that pertain to the commercialization of the HERL technologies. The technology roadmaps developed are discussed in greater detail below. The roadmaps show the various categories along with the corresponding important points. Key categories shown in the roadmaps are: Drivers (both External and Internal), Market Channels, Product Characteristics, Technology Demands and Resource Requirements, as shown in Figure 1.1.

Analyses of these roadmaps led to a set of recommendations for HERL's short- and long-term plans. The goal of the analyses and recommendations was to provide HERL with a coherent, comprehensive guideline and potential pathways for commercializing the Smart Kitchen. With these recommendations, HERL can further explore these pathways to bring their technology from the labs to product stage and then into the market to provide assistance to the targeted user populations.

DELIVERABLES

These analyses were documented in a set of deliverables, described below, and presented to the HERL client in a comprehensive report and presentation (Certificate Program in Leadership and Ethics Class of 2015, 2013).

Technology Roadmap

The technology roadmaps were the first category of deliverables presented within the client report (Certificate Program in Leadership and Ethics

Class of 2015, 2013). These roadmaps organize various categories of information that pertain to the potential commercialization of the HERL technologies. The first part of the deliverable is a chart that shows the various categories along with the corresponding important points. The second part of the deliverable contains further details and information regarding what was noted in the chart. This allows for more detail in order to elaborate on each point, while also providing the ability to have everything organized and presented within a single high-level roadmap chart.

There were five technology roadmaps developed. Four of the five roadmaps are unique for each population that was analysed (Wounded Warrior/ Traumatic Brain Injury, Physically Disabled, Aging and Mass Market). The fifth roadmap is a coordinated roadmap. The roadmaps and commercialization pathways proposed are discussed in the next subsections.

Commercialization Recommendations

The second deliverable was a set of recommendations for various ways of commercializing the Smart Kitchen. Unlike the technology roadmap, there are only four sets of commercialization recommendations; each of these sets was unique to the specific target population and their needs. Included within this deliverable were several sections: a stakeholder analysis; implementation risks; collaborative opportunities/potential partnerships; methods for technology transfer; resources needed; and suggested staffing needs.

Technology Transfer Implications for the Commercialization Recommendations

A further analysis relating to the commercialization recommendations was presented. The first component of this analysis presented a risk assessment for identified risks associated with the specific commercialization recommendations. The second explained the resources needed to commercialize the products along with the anticipated costs associated with each commercialization channel. Finally, the analysis identified staffing needs recommended for commercializing these products.

The resources and staffing identified as being potentially useful in commercializing the Smart Kitchen are summarized in Table 1.1.

Strengths, Weaknesses, Opportunities and Threats (SWOT) Analysis

The SWOT analysis is a way to analyse HERL's position in the market with regard to their strengths, weaknesses, opportunities and threats. This is a

Table 1.1 Resources and staffing needs suggested for proposed commercialization pathways

Resources	Staffing needs
University technology transfer office	Product marketing specialists
Informational resources	Product education trainers
Smart Kitchen website	Spokesperson/lead user
Product briefs/sales sheets	Commercialization specialist

way for HERL to be aware of how competitive they and their products are in the market. It allows the opportunity for HERL to improve on their weaknesses, maintain their strengths, stay aware of their threats and take advantage of their opportunities. The SWOT analysis is a popular method used by a variety of companies and an efficient way to begin the initial analysis of where they stand within the market. SWOT analysis results allow HERL to examine their positioning and the potential pathways for their Smart Kitchen technologies in the context of each of their target populations.

Recommendations

These analyses also led to a set of recommendations for HERL's short- and long-term plans. Recommendations were provided for each target population. The key overall recommendations were to:

1. Work with the Innovation Institute to create plans for patenting and licensing the components of the Smart Kitchen.
2. Partner with insurance companies, not-for-profit groups and kitchen manufacturers to more effectively produce and market the Smart Kitchen and its separate components.
3. Create a sales kit and instruction manual to make the Smart Kitchen more marketable through broad awareness.

The next subsection provides greater detail on the roadmaps and potential commercialization pathways proposed.

Roadmaps for Pathways to Commercialization

Five technology roadmaps were prepared. Four of the five roadmaps are unique for each population that was analysed (Wounded Warrior/ Traumatic Brain Injury, Physically Disabled, Aging and Mass Market).

Table 1.2 Proposed commercialization recommendations for each target population

Target population	Commercialization recommendations
Wounded Warrior/Traumatic Brain Injury	Patent protection Product licensing agreement for domestic manufacturing and distribution Partnering with providers (assisted living/nursing homes) and third-party payers (insurance companies) Product licensing agreements for international markets
Physically Disabled Note: *Demand predicted as being focused on KitchenBot*	Patent protection License technology to an aligned outside company, such as a spin-off company Product licensing agreements for international markets
Aging	Patent protection Product licensing agreement Partnering with providers (assisted living/nursing homes) and in-home care agencies, as well as third-party payers (insurance companies) and special interest groups, such as the AARP
Mass Market Note: *Demand predicted as being focused on Cueing Kitchen and Interactive Display*	Patent protection Product licensing agreements Reach spill-over markets
All	Awareness and marketing campaign to reach target populations, their families and caregivers, providers and payers, as well as special interest groups. These materials can be distributed to potential users/customers and other relevant organizations to raise awareness of the technology and its impacts.

The fifth roadmap is a coordinated roadmap, described below. Examples of these roadmaps are found in the paragraphs below. Through the use of the roadmaps and supporting recommendations, the class project developed a number of proposed pathways to commercialization, as shown in Table 1.2.

Coordinated Roadmap

The coordinated roadmap, shown in Figure 1.2, combines similar, common concerns across the four populations examined.

	Short Term	Long Term
External	Need for assistance Assisted living costs Improved quality of life	Healthcare costs Family concerns Desire for independence Increasing populations Energy efficient In-home mobility
Driver		
Internal	Debug device	Reduce costs
Channels	License arm Patent tactics Form partnerships	License abroad
Product	KitchenBot Voice Control Joystick Control Track Cover Cueing Kitchen Interactive Display Assistance KitchenBot Storage	Part Replacement Customized Bundles Additional Recipes Advanced Inventory
Technology	Voice Activation Software Increased Speed Increased Weight Capacity How-to-Videos	Technological Improvements Software Updates Mobile App Integration
Resources	Funding Sources HERL Kitchen Designers	Health Insurance Companies

Figure 1.2 Coordinated technology roadmap

Wounded Warrior/Traumatic Brain Injury roadmap

This team channeled its research to the Wounded Warrior (WW) and Traumatic Brain Injury (TBI) populations. Figure 1.3 depicts a detailed summary and analysis of the team's proposed commercialization efforts for this target population.

Physically Disabled roadmap

The Physically Disabled team's research revolved around its population's desire for more independence, such as the ability to cook dinner without the assistance of a family member or caregiver. This roadmap focused primarily on the KitchenBot. Figure 1.4 depicts the technology roadmap for the physically disabled target population.

Aging roadmap

The aging population can be reached through commercialization by licensing the Smart Kitchen technologies to a larger firm that has the resources and connections to reach this target population.

Additionally, the Smart Kitchen could be introduced in assisted living settings and nursing homes, potentially as lead users (Franke et al., 2006)

	Short Term	Long Term
External	Cost of Assisted Living WW: Ongoing Conflicts	Improved Safety Precautions TBI: Increased Populations
Driver		
Internal	Role/Involvement of Caregivers	Desire for Independence
Channels	License Product Create Partnerships	Patent Protection License Abroad
Product	Smart Kitchen Sensory Design	Part Replacement Customized Bundles Additional Recipes WW: Technology in Mortgage Free Homes Sold in New Homes
Technology	Refine Current Products Speed-Up/Stronger Arm Increased Technology	Technological Improvements Software Updates Develop Apps
Resources	HERL Assisted Living Homes WW: Government Grants	Website Health Insurance Companies TBI: Relations with Brain Specialists

Figure 1.3 Wounded Warrior/Traumatic Brain Injury technology roadmap

	Short Term		Long Term	
External	Improves Quality of Life Joystick & Voice Control	Cost to Install Price Sensitivity How-to- Videos	Payers Price Promotions Energy Efficient In-Home Mobility	Service Outside of Home
Driver				
Internal	Debug Device Safety Regulation Liability	Fulfill Mission Commercialize	Reduce Costs Sales Kit Revenue Sources	Contracts Perform Research
Channels	License arm Patent Form partnerships		Ongoing Renewal Fees Outsource Production License Abroad	
Product	KitchenBot Voice Control		Multiple Designs Testimonials Extend Track	Home Designers Water Resistant Arm Child-Friendly
Technology	How-to-Videos Increased Weight Capacity of Arm Increase Voice Capabilities		Software Updates Improve Technology	Detachable Arm Mobile App Aesthetics
Resources	Partners Funding Sources Knowledge of Regulations		Associated Fees Outsource Production	Contracts Mobile App

Figure 1.4 Physically Disabled technology roadmap

to provide direct feedback on implementation and use of the products and to further inform ongoing development of the Smart Kitchen to meet the needs of the user populations. Third-party payers, such as insurance companies, could also be engaged with to subsidize costs for individuals seeking the product, perhaps offsetting increased costs for assisted living or nursing home by delaying admission and keeping the aged in their own familiar settings. These payers may also serve as an additional communication channel to reach more consumers and make them aware of options utilizing the Smart Kitchen technologies.

Mass Market roadmap

In their analyses of the mass market population, channels such as restaurants and cooking schools were identified in the short term, and it was suggested to eventually move toward commercialization paths that could reach individual consumers with sufficient disposable income to afford a kitchen redesign in the longer term. These consumers are looking for increased efficiency in the kitchen, as well as instruction on how to cook new, unique recipes with the help of the Cueing Kitchen.

DISCUSSION

This project developed insights into commercialization for both the student participants and their researcher clients. They determined that Smart Kitchen may develop into a lucrative technology to commercialize, with significant royalty opportunities accruing to the university and inventors, as technology transfer pathways are developed to mature these technologies and move them into the commercial marketplace.

Addressing our research questions, we identified a number of potential pathways to successful commercialization of the Smart Kitchen innovations. Leahy (2003) had introduced three possible pathways for technology transition of assistive technologies: standard licensing, e-commerce and market cultivation, while Anokhin et al. (2011) suggested four possible modes of commercialization for misfit technologies: internal development, partnering, spin-offs and externalization. All of these mechanisms were incorporated into the technology roadmaps and recommendations developed, with the exception of e-commerce. The complexity of the Smart Kitchen technology, coupled with its need to be integrated into a kitchen by a competent contractor/installer, eliminated the e-commerce option from further consideration.

In examining the four technology roadmaps developed, we determined that the potential pathways are not identical for all three components of the Smart Kitchen. Two populations (Wounded Warrior/Traumatic Brain Injury and Aging) were very similar in the proposed pathways, while the Physically Disabled pathway was similar, but focused primarily on the KitchenBot technology of the Smart Kitchen and is a potential pathway to a spin-off company for the niche market of the KitchenBot. The Mass Market population had similar pathways, although significantly different partnering opportunities suggested for reaching a wider variety of spillover markets within the mass market. These partnership opportunities included partnering with a restaurant chain or cooking schools – a spillover market; kitchen designers – fitting the technology into a typical home; high-end consumers – remodeling their homes; and kitchen or appliance manufacturers – extending current product lines with the Smart Kitchen technology.

As discussed earlier, a number of resources and capabilities were recommended as necessary to innovate and commercialize the Smart Kitchen. These included the use of the university technology transfer office, development of informational resources, such as a Smart Kitchen website and product information for the education of potential users and funders, and enhancing the HERL research team with personnel to support technology transfer. These personnel could include product marketing specialists to raise awareness and understanding of Smart Kitchen, product education trainers who can provide user training and support Smart Kitchen training and awareness activities, and commercialization specialists to support licensing and partnership development. The role of spokesperson/lead user would be undertaken by someone who uses the Smart Kitchen, has domain expertise and can serve as an advocate or product evangelist (Steinhardt, 2010) for the Smart Kitchen. Either this role could be filled internally or externally, although Sindhav (2011) argues that consumers are more likely to become product evangelists when they help co-create the product, so an external spokesperson/lead user may be ideal.

Further research and commercial availability of these technologies would allow HERL to fulfill its mission to improve the quality of life through use of the Smart Kitchen, and would have a direct impact on the target populations, their families and caregivers. Potential partnerships could provide opportunities for relationships in a number of different channels to reach broader markets with these technologies. These partnerships could be with companies for joint development and commercialization, as well as with interest groups to build market credibility and awareness (for example, Wounded Warrior Foundation and AARP).

CONCLUSIONS

This service-learning project provided students with opportunities that relate to real-world experiences. It provided them with experience in identifying stakeholders, understanding stakeholders and their needs and working with multiple stakeholders. While doing this, they learned to consider both business and societal/stakeholder impacts and apply these considerations in their analyses.

They also gained significant experience working one on one with a client in a complex project, while learning and overcoming the challenges of managing complex projects. One such challenge was in addressing the client's needs and wants, while still accomplishing the task at hand. During this class project, they both collaborated with peer teams and gained experience in both direct and indirect leadership throughout the entire analysis and documentation process. They combined peer input, online research, sponsor input and other information together to create a final product, and presented this report and presentation to their client and interested parties. This service-learning project was a hands-on experiential learning opportunity that introduced students to concepts of strategy planning and technology roadmaps, commercialization and technology transfer. They also gained an understanding of university research processes. This project prepared students for later application of these skills in real-world tasks, such as intellectual property transfer, market research and market development, and mergers and acquisitions (M&A). This project was an example of 'teaching by stealth' through the ecosystem (Levie, 2014) and experiential activities, by providing students with a problem regarding a technology and its transfer into commercialization, and allowing students to learn about technology transfer by engaging in it, rather than just taking a class in the commercialization of new products.

The goal of the analyses and recommendations was to provide HERL with a coherent, comprehensive guideline for commercializing their Smart Kitchen. With these recommendations, HERL can bring products to the markets that are beneficial to its target users, and also allows HERL and the University of Pittsburgh to reap the possible benefits of commercialization. A key measure of success of QoLT is the widespread use of the technologies that enhance the quality of life of people with disabilities and older individuals (Cooper, 2008). Our results may provide insights into potential pathways to commercialization success and adoption of the Smart Kitchen technologies by the targeted populations, and may also provide lessons for others involved in technology transfer. By examining multiple target populations, we were able to demonstrate that commercialization pathways may not be a single path, but may be dependent on a number of factors such as target population and institutions in the target space. Another lesson was that research projects moving toward commercialization may need to augment their staff and resources, either through the use of university technology transfer offices or through augmentation of projects with resources focused on outreach and commercialization.

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