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Abstract

This paper examines how the concept of public values can be operationalized in an ongoing public initiative to stimulate innovation in an emerging technology. Our study focuses on Innovation Corps (I-Corps) –a program initiated in 2011 by the National Science Foundation (NSF) to accelerate the process of commercializing science-driven discoveries. The I-Corps method has since spread rapidly across multiple US agencies. Separately, there has also been heightened attention to the early anticipation and mitigation of the implications of emerging science and technology. Drawing on the case of nanotechnology, the paper considers how public values related to nanotechnology commercialization can be integrated alongside the fast start-up procedures embedded in I-Corps. We use a public values framework to pose societal-impact questions that can be probed in parallel with the current I-Corps process, highlighting values such as identification of societal problems that the technology might potentially address; types of potential customers likely to be overlooked; groups who might oppose the application as well as those who might support it; and potential environmental, health, and safety risks. The paper discusses the challenges of adding specifications related to equity as well as safety in efforts to foster rapid commercialization and considers how these can be integrated within the I-Corps approach.

Keywords: public values; I-Corps; societal implications; nanotechnology

Introduction

Public value mapping (PVM) is an approach that examines the outcomes of public policy interventions in the context of public articulations of the goals of those interventions. PVM typically proceeds by studying the hypothesized and the realized causal links between the public goals and the societal outcomes of policies (Bozeman, 2007; see also Alford and Yates, 2014). Its proponents contrast PVM with conventional economic development measures of impact. For example, Bozeman and colleagues (2015, pp. 35-36) state that "the Public Value criterion counterbalances some of the emphasis on economic impacts of technology transfer... without direct attention they are easily set aside or ignored." This opposition is not surprising. Not only do conventional science and technology programs often rely on economic development measures such as numbers of new companies or jobs created, but it is also not usual for programs with non-economic objectives to rely on economic development outcomes to justify their programs. In part this is because economic development measures are more amenable to information collection, quantification, and reporting. Additionally, economic development benefits also produce spillovers beyond the individual firm gains by distributing benefits such as reduced prices or better quality to customers or sharing practices with other firms in the same location (Feller and Nelson 1999). However, as Bozeman and colleagues argue, even where economic impacts are positive overall, there can be a worsening of divides between the rich and the poor. They argue that public values may include some dimensions related to economic development, such as having a fulfilling job, but they go further to give consideration to better health, improved safety, or reduced hunger.

Although conventional evaluations of science and technology commercialization programs generally have given little attention to public values to date, there is growing interest in incorporating public values into science and technology based programs including those which seek to foster economic development, innovation, and commercialization (Bornmann 2012; Boons et al., 2013). Moreover, the increased emphasis on public values in innovation and commercialization is not confined to the public sector. Technology startups in the private sector increasingly include societal targets in their pitches to venture funders (Lounsbury and Glynn 2001; Frydrych et al., 2014).

This paper examines how public values can be mapped into a public program to stimulate the commercialization of science and technology – the Innovation Corps (I-Corps) program. I-Corps was begun by the US National Science Foundation (NSF) to accelerate the pace of commercializing science-driven discoveries. Subsequently, the I-Corps commercialization process has expanded beyond NSF discoveries to research programs with a greater "mission" orientation sponsored by the National Institutes of Health, Department of Energy, Department of Defense, National Security Agency, and the Department of Agriculture as well as to commercialization programs administered by the Small Business Administration. Indeed, the White House referred to this expansion as "Scaling up a rigorous entrepreneurship training program developed by the National Science Foundation" (White House, Office of the Press Secretary 2015). The rapid spread of the I-Corps process across multiple US agencies highlights the importance of considering how the approach reflects and incorporates public values. Our paper explores the extent to which the I-Corps approach can not only promote the application of research-intensive technologies to potential customers but also how societal challenges can be considered alongside these private sector needs.

Background

The concept of "public values" has many connotations (Bozeman, 2002, 2007; Benington and Moore, 2010). For the most part, public values are viewed as comparable to societal or collective goods benefits not reserved for the private sector (Jørgensen and Bozeman, 2007). We use the definition provided in (Bozeman, 2007, p. 37): "A society's 'public values' are those providing normative consensus about (1) the rights, benefits, and prerogatives to which citizens should (and should not) be entitled; (2) the obligations of citizens to society, the state and one another; (3) and the principles on which governments and policies should be based." Public values research has identified problems when private economic development outcomes are superimposed on programs and institutions with public targets. For example, some detractors have contended that rising emphasis on university commercialization has undercut the fundamental educational purpose of universities (Kleinman, 2003; Slaughter and Rhoades, 2004; Henkel, 2005). Commercialization pressures have the potential to have a similar effect on the mission of national laboratories, with defense and national security, as well as research, being at risk (Mowery, 1988; Coursey and Bozeman 1992; Butler and Birley 1998; Aronowitz, 1999; Jaffe and Lerner, 2001; Kassicieh et al., 2002). Public values mapping distinguishes the core public values of a program, for example by using legislative or other records, then develops indicators to represent those values, and applies these indicators to program assessments.

Public values mapping can be considered alongside other efforts to ensure attention to societal impacts. For example, in the early 1990s, an Ethical, Legal, and Social Implications (ELSI) program was established by the National Institutes of Health and Department of Energy to provide guidance about societal consequences of mapping the Human Genome Project. About five percent of the budget for the Human Genome Project was allocated to ELSI initiatives, including a research component, public testimony, educational materials, and international collaborations. External reviews of the program have noted mixed effects of the program on influencing the human genome scientific research agenda (Fisher 2005, Marshall 1996).

In the early 2000s, attention to societal issues was incorporated into the design of the US federal program to develop emerging nanotechnologies – the National Nanotechnology Initiative. This reflected concerns about the potential risks of nanotechnology as well as a desire to avoid the societal backlashes experienced by other technologies such as genetically modified foods. The 21st Century Nanotechnology Research and Development Act (P.L. 108–153), which became law in 2003, had a clear objective for societal issues to be integrated into nanotechnology research.

Section 2 (b)(10) of the act called for the creation of a research program in the societal implications of nanotechnology, required nanoscale science and engineering research centers (NSECs) to consider societal implications, incorporated societal issues alongside scientific research, and called for nanotechnology to improve the quality of life for all citizens and to solicit public input. One of the four goals of the National Nanotechnology Initiative is to support responsible development of nanotechnology, alongside research, commercialization, and education. Even commercialization is expressed as transferring "nanotechnology into products for commercial and public benefit" (National Nanotechnology Initiative, 2015). Public values are thus embedded into the legislative framework for developing emerging nanotechnologies in the US.

In recent years, a range of principles have been put forward in Europe, as well as in the US, to encourage responsible research and innovation, again highlighting attention to public values in science and technology and the real-time assessment of emerging technologies (Guston and Sarewitz, 2002). The European Union has focused attention on responsible research and innovation in its major research funding programs (European Commission, 2013). An influential definition of responsible research and innovation has been put forward by von Schomberg (2011), emphasizing transparency and interaction between societal actors and innovators and attention to ethical acceptability, sustainability and societal desirability. In the UK, Rayner et al. (2013) published "The Oxford Principles" to guide the development of geoengineering, comprising regulation as a public good, public participation in decision-making, research disclosure, independent assessment of impacts, and robust governance structures before deployment. The Engineering and Physical Sciences Research Council, one of the UK's leading funding bodies, has established a Framework for Responsible Innovation which highlights the importance of anticipation, reflection, engagement and action for researchers and research organizations (Stilgoe et al., 2013; EPSRC, 2013). Similarly, in the US, Roco et al. (2011) stress four aspects of the responsible governance of nanotechnology for societal development: transformative across disciplines and sectors; attention to equitable access and environmental, health, and safety concerns; participation across governmental agencies and other stakeholders; and a long-term perspective with measures that anticipate and adapt.

These recent statements and principles, including those which are incorporated into legislation and governmental guidance, pledge that public values should be given significant consideration in programs designed to conduct research and commercialize the results. Yet, while indicators of research (such as journal publications and citations), invention (number of patents), and commercialization (spinoff companies and their sales) are readily available, we do not see a similar attention to the creation of gauges of public value. We seek to address this gap by exploring how public values can be more explicitly incorporated into a prominent science and technology commercialization initiative – the I-Corps program. Recognizing the complexities and drawbacks associated with simple quantitative measures, we put forward an approach that identifies a set of questions with public values implications that parallel the commercialization questions that are often used to seed the I-Corps process. The next section of the paper describes I-Corps. We then investigate how public values can be mapped into this program.

I-Corps

I-Corps was started at NSF in 2011 to accelerate the commercialization of science-intensive research. "One of the major goals of the program is increasing the economic impact of NSF-funded research," according to the program director (Grose, 2014, p. 24). I-Corps builds upon approaches developed by Silicon Valley entrepreneur and author Steve Blank to incorporate greater customer input in to the startup process (Blank, 2013). I-Corps created an infrastructure that provides entrepreneurship training through a set of "Nodes." I-Corps Nodes are regional locations at universities that deliver entrepreneurship training using the I-Corps curriculum. Nodes also are the focus of efforts to enhance the commercialization infrastructure of their region and feedback information to improve the I-Corps service. The first three I-Corps nodes were at Stanford

University, Georgia Institute of Technology (Georgia Tech), and the University of Michigan. Four other nodes, comprised of three or more universities, were added a few years later in New York City, Washington DC, Southern California, and Texas.

The training performed at the nodes is directed towards three-person teams. These teams are comprised of a principal investigator who has received an award from NSF (or from one of the other agencies who subsequently replicated the program) and completed the research, an "entrepreneurial lead" who is usually a graduate student or postdoctoral fellow, and a mentor who typically has private sector familiarity with transferring academic research into the commercial market. NSF provides $50,000 to support the efforts of the I-Corps team, primarily for travel and prototyping. These awards are given after screening interviews to determine likely commercialization success.

Training is a key element of I-Corps. A six-month program is delivered, drawing on Stanford University's Lean Launchpad (Engineering 245) curriculum (Blank et al., 2010; Blank, 2013). The program starts with a three-day boot camp which teaches the basics of business development and how to reach out to customers. The business development aspect is centered on the Business Canvas Model (Osterwalder and Pigneur 2010) – a stripped-down version of a conventional business plan. The Business Canvas Model addresses nine factors in the construction of a viable business model. The model begins with brainstorming "hypotheses" or assumptions about who is the customer of a given product or service, what the customer values, and how money can be made – the "value proposition." These hypotheses are then viewed in context of customer needs and validation. Methods are identified to establish customer relationships and channels, while maximizing revenue. Internal factors are considered, including defining the key partners, activities, and resources necessary to bring the concept to market. In addition, the cost side of the financial equation is estimated to assess potential profitability.

The most important aspect of the training is the testing of the hypotheses about the value proposition compared to customer needs. The boot camp provides initial training in how to talk to customers. Then, I-Corps participants set aside 15 hours a week for "customer discovery," which involves interviews and meetings with potential customers, investors, and business partners. The mentor plays an important role in helping to arrange these meetings. After each set of meetings, the team reviews and iterates or "pivots" its hypotheses to obtain a better match between customer needs and product offerings. The training lasts for six weeks, with the remaining 4.5 months devoted to prototyping of what is known as development of a "minimal viable product." The overriding objective of the approach is to accelerate commercialization not by writing exhaustive business plans but through iteratively engaging with potential customers to rapidly develop a product for which there is demand and market.

At the end of the six-month period, the team is ready to decide if the business model is viable as a business, as a technology that could be licensed to another business, or that it is not worth pursuing as a business venture. This point is also known as the "go-no go" decision. When training is completed, the I-Corps Team returns to the home university. Having supportive infrastructure for commercialization in the region is thus important because otherwise the lack of infrastructure could stymie entrepreneurial efforts. Such infrastructure includes capabilities to deal with intellectual property issues, financing needs, and personnel and management requirements (Swamidass 2013). I-Corps helps build up these capabilities at universities that have entrepreneurship programs in what is known as "I-Corps Sites." I-Corps sites provide training (similar to that provided at I-Corps Nodes), prototyping and proof-of-concept support, networking, and small amounts of funding.

I-Corps is administered by NSF's Directorate for Engineering. NSF annual funding for I-Corps grew from $20.5 million in FY 2014 to $30 million in FY 2016 (NSF 2015, 2016). Additional support for the program comes from the Kauffman Foundation and the Deshpande Foundation. In the period from the start of 2013 through to October 2016 (46 months), NSF reports 864 I-Corps team awards totaling about $42.7 million. Over the same period, NSF awarded a further $43 million in program funding. This includes about $29 million for I-Corps nodes and sites and $11.5 million to the National Collegiate Inventors and Innovators (NCIIA), rebranded in 2014 as VentureWell, a non-profit corporation that works with NSF to train and support I-Corp teams (authors' analysis of I-Corps awards in the NSF Awards Database, https://www.nsf.gov/awardsearch, as of October 25, 2016). Other federal agencies that have established or co-sponsored I-Corps or similar programs include the Advanced Research Projects Agency-Energy, the Departments of Agriculture, Defense, and Homeland Security, the Department of Energy (Energy Efficiency and Renewable Energy), the National Institutes of Health, the National Security Agency, and the Small Business Administration (see also White House, Office of the Press Secretary 2015).

Despite the growth of the I-Corps program, evaluations of the program have been relatively thin. The primary evaluation of I-Corps uses post-course surveys. NSF contracted with NCIIA/VentureWell to develop, administer, and analyze post training questionnaires. VentureWell also organizes the National Innovation Network to promote knowledge sharing. The I-Corps questionnaires ask participants to rate course components, likelihood to undertake steps to start a company (such as prototyping, seeking funding, the "go-no go" decision), and further use of course components in university instruction. Results from activity reporting and the post-participant surveys indicate that knowledge of the business canvas model more than tripled after I-Corps and 70% of participants shared this knowledge with their colleagues (Weilerstein 2014). Fifty-seven percent and of the 2011-2012 cohort went on to found companies of which 10% received equity financing (Grose 2014). One case study described how an I-Corps participant had broader effects on the campus's entrepreneurial culture (University of Wisconsin-Milwaukee, 2015). Yet evaluation approaches using robust comparison group studies to test whether these outputs would have occurred without the program have not been undertaken. The program has a self-selection bias built into the award process which is not controlled for. Nor has longer term follow up with the teams been conducted or at least publicly reported.

I-Corps and Social Benefits

Building on the "lean startup" methods advocated by Blank (2013), I-Corps positions its approach as an improvement on conventional business planning for entrepreneurs. Traditional business plans often require a lengthy period of time to develop, require investments of human and other capital for planning, and make many assumptions about market, partner, and financial unknowns (Lange et al., 2007; Gately and Cunningham, 2014). In contrast, the I-Corps approach operates on a shorter timeframe, uses a standardized methodology that academic researchers pursuing commercialization can apply, and provides data and insights from customer and partner feedback. From the perspective of socio-economic impacts, the I-Corps approach promises to speed the transfer of knowledge from upstream basic research into downstream products and services, and assumes that positive societal impacts are implicitly represented by economic benefits. However, we seek to encourage the explicit probing of societal implications alongside consideration of economic aspects. This includes reflection on, and attention to, the effects of the technology on societal needs, environment and health and safety, ethical considerations, and equity and economic dislocations.

While conventional business planning allows greater time and scope for exploring various pathways and ideas prior to formal market entry (Chwolka and Raith, 2012), discovery approaches such as I-Corps have the potential to limit the amount of time for societal reflection depending on the characteristics of customers and partners interviewed about the potential product. Such approaches, while they emphasize customer engagement, can lack sufficient flexibility and space in the timetable for exploration of impacts on broader societal values. Where innovations are incremental, conventional planning approaches are more likely to allow time for reflection on societal aspects. If the innovation is more of a breakthrough, both commercialization approaches are restricted in their ability to gather societal information, with the planned approach suffering from too many unknowns about the vision for the breakthrough, while I-Corps additionally lacking sufficient time to explore these visions (see Table 1).

Table 1. Author Exploration of the Relationship Between Commercialization Planning Modes, the Nature of Innovations, and Societal Reflection in Current Practice

	Nature of Innovations	
Commercialization	**Incremental**	**Breakthrough**
Planned approach	*Time can be sufficient for societal reflection*	*Limited (vision) for societal reflection*
Discovery approach (e.g., I-Corps)	*Limited (time) for societal reflection*	*Minimal (vision and time) for societal reflection*

Mapping Public Values

Although societal considerations are typically not deeply embedded in discovery approaches to commercialization, we suggest that it is possible and feasible to incorporate these considerations. Moreover, in so doing, discovery approaches will be less likely to succumb to unforeseen societal roadblocks and will be more responsible. We put forward a framework to explicitly map public values into the I-Corps process (Table 2). The table focuses specifically on components of the I-Corps process, examples of questions that have been used to test the relationship between the product/service features and customer, and public value questions mapped alongside these I-Corps components and questions. All I-Corps question examples come from interviews with two of the specialists who have performed training at the Georgia Tech I-Corps node. Many of the Georgia Tech I-Corps trainers have started technology companies and have several years of experience in implementing the I-Corps program as well as a similar program at Georgia Tech called Startup Gauntlet. We note that there is flexibility in the questions used in the I-Corps process, with each team working with the most appropriate entry questions. Thus, the table should be viewed as illustrative of the kinds of questions that are and can be probed.

Many of the examples we use to explicate the public values implications shown alongside these I-Corps starting questions come from the nanotechnology domain. Nanotechnology is a science-intensive area that has shown to be broadly multidisciplinary, thus applicable to many scientific fields (Porter and Youtie 2009). It also has been shown to have the characteristics of a general purpose technology, thus encompassing many different types of applications (Youtie et al., 2008). Investments also have been made by the NSF and other agencies in social and ethical research and outreach initiatives as called for in the 21st Century Nanotechnology R&D Act. For these reasons, we believe that nanotechnology is a useful lens through which to examine components of the I-Corps process.

Table 2. I-Corps Components and Examples and Public Values Questions

I-Corps Components	Examples - I-Corps Questions	Examples - Public Values Questions
Novel functionality	What is the technical specification that makes this application unique? What problem does this technology solve? How is this solution better than the status quo?	What societal problem does this technology solve?
Customers	Who will think this application is valuable or useful? How would you contact them?	What types of potential customers would you likely overlook? Who might find this useful but might not be able to pay for it?
Partners	Who might promote this new technology? Who would be a good partner for bringing this technology to market?	Who might oppose this technology? Who might lose their job if this technology is widely commercialized?
Value proposition	What are the key activities that are required to deliver value to the customer?	Are there any potential environmental health, and safety risks from this application?

Novel functionality. Novel functionality in the I-Corps context refers to the technical specification of the application, how it solves a problem, and solves it better than incumbent products or services. Georgia Tech I-Corps trainers report that many I-Corps participants have difficulty spanning the boundary between the research and a specific application that has value in the market. These trainers draw on a range of questions to help researchers think about their research from the perspective of the market. Examples of these questions include:

- What does this technology do?
- What is the technical specification that makes this unique?
- Why is that useful?
- And then, why is that useful?
- What problem does this technology solve?
- How is the problem being solved right now?
- How is this solution better than the status quo?

Most of the questions focus on the technical target of the research. They try to get researchers to develop a problem that is technically solved by the research or that makes the research useful. An example is a technical specification that a nano-enabled device is three centimeters by 10 centimeters. This specification makes the device useful because the technology is portable and can be taken in the field rather than only being able to be used in the laboratory.

We envision a parallel set of questions that get the teams to focus on societal problems solved by the technology. While one might imagine that teams could draw on sources such as the United Nations Millennium Goals, we expect that making the leap from a technical specification to a societal goal might be overreaching. It could lead to overly generalized statements about the societal issues that the technology could address. The risk in this is analogous to "greenwashing," in which misrepresentative or exaggerated assertions about the environmental performance or benefits of a product or service are made (Laufer, 2003; Delmas and Cuerel Burbano, 2011).

Some research is likely to be more closely linked to societal needs than others. In the case of nanotechnology, research related to nano-enabled solar cells, nanogenerators, zeolite nanocomposites reverse membranes have a direct connection to green and sustainable development (Shapira and Youtie, 2015). In contrast, synthesis and characterization of graphene, while important for subsequent applications, may lack the specificity to make such direct connections. Care should be taken in leading researchers to think about their contribution to societal goals in these cases.

Customers. A central I-Corps tenet is to identify the customer for a particular application, then iteratively contact these customers to obtain feedback on the potential product. Most of the questions that guide this process are some variant of: “Who will think this technology is valuable?” After each set of contacts, the research team member reviews the customer feedback with the mentor and trainers and “pivots” either by changing the product or the market to reflect this feedback. For example, interviews may suggest that the product is not relevant to sell directly to customers (B to C), but is more relevant to sell to corporations (B to C), so the team will make changes to the market and in some cases to the product to make the market or product more viable.

Societal considerations are two-fold in this area. The first concerns the representativeness of the customer list that the entrepreneurial research participant develops with the mentor. While it is important for the list to reflect business aspects of the process, we maintain that attention should also be paid to important societal groups. These groups would prominently include government agencies, especially funding and regulatory agencies, foundations, and non-governmental organizations. They also should include underrepresented groups such as underrepresented minorities or those who are physically or economically disadvantaged. In the case of the latter, new cancer treatments might be beneficial but unaffordable to economically disadvantaged groups. The second concerns groups who might suffer from economic displacement if the application is widely diffused. Applications are most useful if they benefit a wide range of customers. A case in point: artificial intelligence researchers should be aware of studies of tasks likely to be taken up by robots (Ford 2015). While individual teams cannot solve all aspects related to job displacement, they should explicitly recognize and reflect on what happens to those who may be displaced, and this may lead to re-targeting of the application (for example, towards particularly undesirable tasks), enhancing rather than displacing human capabilities, and building retraining (for instance, in the programming and maintenance of autonomous systems) into implementation models.

Partners. Partners are typically viewed as organizations that might promote a science-based application through the provision of resources or performance of activities. A key step in the process, once the value of the application and customer are addressed, is to identify who would be a good partner to bring the technology to market. Currently, most of these supplier identification efforts focus on suppliers.

From a societal standpoint, there are other partners that can, and are, involved in the deployment of emerging technologies. Government agencies can provide resources through public procurement of innovative goods to address missions not able to be achieved with off-the-shelf solutions (Georghiou, 2007). The US has a long history of use of public procurement that leads to private sector innovation even though there is no explicit policy to promote this method (OECD, 2011). These procurement policies extend across a range of policy areas. Pre-commercial procurement through the Small Business Innovation Research (SBIR) program is among the most prominent in the US. This program has multi-agency involvement by 11 agencies with extramural research budgets of more than $100 million, with the Department of Defense accounting for half of

SBIR procurements, followed by the Department of Health and Human Services, National Aeronautics and Space Administration, Department of Energy, and NSF. The Defense Research Projects Agency and other agencies of the US Defense Department have served a role as a large early user of nascent technologies such as transistors and switched networks (an Internet precursor). Regulations such as Corporate Average Fuel Economy standards for automobile and performance standards in the National Appliance Energy Conservation Act of 1987 for refrigerators have had the most broad-based effects on the largest number of Americans. Other examples of regulatory demand-side initiatives in the US include the Orphan Drug Act of 1983 which provides favorable patent protection to pharmaceutical firms in rare disease areas, the Sarbanes-Oxley Act of 2002 which encouraged innovation in financial information technology and accounting, and the Health Information Technology for Economic and Clinical Health Act of 2009 which has encouraged innovation and standards development in electronic medical records. Similar activities are promoted by foundations. In sum, conceptualizations of partners can be too narrow if partners are drawn from conventional business models. I-Corps teams should (and some do) reach beyond the private sector in their view of partners.

Not all partners are supportive of all emerging technologies. Some might seek modifications or even oppose the technology. A risk of not engaging early on with these partners could be public pressure to slowdown or place a precautionary hold on particular forms of research commercialization (or in some cases, the research itself). Nongovernmental organizations (NGOs) such as the Canadian ETC Group have called for moratoriums on nanotechnology commercialization until more is known about the occupational and environmental and health risks. The International Union of Food, Farm, and Hotel Workers called for a moratorium on nanotechnology in food and agriculture until toxicological and socioeconomic risks were better understood. Similar views were held by the International Center for Technology Assessment, which has aggregated nongovernmental organizations around issues of nanotechnology risks. On the other hand, DuPont and the nongovernmental organization Environmental Defense partnered to create the Nano Risk Framework; this is a voluntary code of conduct for assessing and managing environmental and health and safety risks associated with nanotechnology ahead of any specific US governmental regulations for nanotechnology (Ferrari, 2010).

It should be noted that NGOs are not the only source of opposition to commercialization of an emerging technology. Individuals can also generate sufficient issues to challenge commercial entry. A specific example is Pure Plushy Inc., which stopped using a nanosilver antimicrobial coating for a children's soft toy (Benny the Bear) because a blogger questioned why the company did not provide information about the formulation of the coating (Wetmore, 2010). We suggest that teams seek, and allow for, public participation and feedback on issues that are likely to be sensitive. If early signals of potential user or public concern can be surfaced and acted upon, subsequent issues may be avoided that could lead to costly problems.

Value proposition. The value proposition is the relationship that links the product or service with the needs of the customer. It focuses on how a product creates value by solving a customer problem or delivering new benefits. Value can be conveyed as "pain relievers" (such as reducing costs, lowering risks, or decreasing mistakes) or "gain creators" (such as providing savings, yielding better performance and quality, or enhancing accessibility) (Osterwalder, 2012).

We propose that one of the societal correlates to this activity of describing the value proposition is to think about environmental, health, and safety risks that the application poses. It is important to understand that the environmental, health, and safety issues associated with particular emerging technologies are not always clear defined or mutually agreed. First, in many emerging technologies, there is lagging gap between environmental, health, and safety research about the technology and fundamental research on that technology (Youtie et al., 2011). The lack of information to span this gap usually results in avoidance of specific regulations concerning that technology in favor of studies, reporting, codes of conduct, sharing of best practices, and international collaborations. Second, labeling that communicates the presence of the emerging technology is important for transparency in both an ethical sense (to communicate risk) and an economic sense (to give the market full information), yet is difficult to implement. Yet many features do not lend themselves to "drawing a line" dividing existing and new technologies. And labelling is not easily monitored by government regulators or nongovernmental organizations. We would suggest that I-Corps teams explicitly consider environmental, health and safety aspects of proposed products, and seek to address through remediation and transparent labeling (for a further example of questions that might be posed here, see CNS-ASU, 2015). This could also include undertaking life-cycle analysis (LCA), to probe environmental, health, and safety aspects in all stages, from materials input, manufacturing, distribution and use, maintenance, and end-of use disposal or recycling, and to optimize or adjust the product based on LCA insights.

Discussion and Conclusions

Are public values really in opposition to economic development program values? This paper argues that not only can they be conceived of as compatible, but that they can benefit one another. Arguably, there are no added public values and societal benefits if a new technology does not get deployed into the marketplace. This is highlighted by a National Academy of Sciences panel in a statement on the responsible development of nanotechnology:

> responsible development of nanotechnology can be characterized as the balancing of efforts to maximize the technology's positive contributions and minimize its negative consequences. Thus, responsible development involves an examination both of applications and of potential implications. It implies a commitment to develop and use technology to help meet the most pressing human and societal needs, while making every reasonable effort to anticipate and mitigate adverse implications or unintended consequences (Committee to Review the National Nanotechnology Initiative, p. 73).

By the same token, we do not intend to suggest that all commercialization of new technologies is beneficial. Technologies can have undesirable side-effects, some of which can be damaging or harmful. Deleterious effects are especially likely when public values concerning societal problems, equitable treatment of potential customers, dislocation effects, and environmental, health and safety risks are not taken into account (EEA, 2013). We suggest that that early consideration of public values can assist with commercialization, and may reduce the potential for harm caused by a new technology if not optimizing benefits and chances of success. Commercialization should be conceived not as antagonistic to public values, but rather as a mechanisms for the incorporation, co-existence and balancing of values. In particular, we show how public and economic values can be examined together through a case illustration of the I-Corps program; a program designed with economic development goals to speed research-intensive emerging technologies to market. We set out an approach that promises to spans the gap between business development and public values by mapping public values alongside conventional I-Corps components. The mapping we present is not intended to be the only way to express public values in the development and commercialization of emerging technologies. Rather, the I-Corps example is intended to illustrate one way in which public values might specifically be embedded in the operational processes of a public technology commercialization program.

What benefits would I-Corps gain from explicit attention to public values mapping? Would embedding public values with current I-Corps components constitutes an improvement or add unnecessary burden? A strength of I-Corps is that it has minimal requirements and it stimulates the entrepreneurial researcher leave the lab to talk to potential customers about proposed applications. Yet, it is entirely consistent for entrepreneurial teams engaged in this agile process to early on consider societal implications, to discuss these with possible users and other stakeholders, and to adjust and pivot their approach based on the feedback and insights received. We are now in an era where technological commercialization without attention to public values is increasingly risky, if not unacceptable. For a program such as I-Corps, incorporating a public values framework into its processes ensures that it remains relevant and sustainable, and will guide entrepreneurial teams to ask (and seek answers to) the kinds of questions that society and public policy now increasingly expects business to address. Moreover, building societal and public values into processes to commercialize emerging technologies should help entrepreneurs to anticipate potential downstream issues, and is likely to make for more effective as well as more responsible applications.

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