Open Debate

Exploring How Material Demonstrators Accelerate the Transition to a Circular Bioeconomy

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Abstract
Taking ideas to market can be a long, iterative, and complex process. When dealing with new bio-based materials, understanding factors that help bridge the lab-to-market gap and how materials are selected for new product development have the potential to speed up the transition to a circular bioeconomy. This article defines abstract and conceptual material demonstrators and explores how they support the innovation process in different ways. Nine roles are identified, including how material demonstrators contribute to generating and expressing new ideas, enable a shared understanding of technology, support the discovery of market value and the visualization of potential applications as well as helping to articulate internal and external strategies and communications. Abstract and conceptual material demonstrators are exemplified with both technology-driven and market-driven bio-based materials used in packaging.

Keywords
Bio-based Materials Demonstrators Lab-to-market gap Bioeconomy
Introduction

Innovation, the process of creating and delivering new customer value in the marketplace (Carlson & Wilmot, 2006), can be a lengthy process, especially in cases where new technologies need new markets. The timeline for a lab-to-market success can take over 18 years (Von Windheim & Myers, 2014). The increasing demand to replace fossil-based materials with materials from renewable sources is putting pressure on companies to shorten the lab-to-market timeline and accelerate the transition to a circular bioeconomy, in which environmental, social and economic sustainability drive resource efficiency. For this to happen, collaboration between industries and disciplines will increase, recovery and recycling of materials will become a priority, and waste-streams in one industry will become feedstock to another industry (Stark & Matuana, 2021; Corrado & Sala, 2018).

Materials have two roles in products: performing technologically and contributing to product personality (Ashby & Johnson, 2014). Materials must function according to the intended use of the product and have properties that impart the desired levels of durability, recyclability, etc. Active materials that can change their properties based on changes in their surrounding environment can be both attention-grabbing (e.g. open in an oven like a blooming flower) and functional (e.g. space-saving before activation thereby transporting less air).

Material demonstrators are useful in the innovation process, especially for bio-based materials, which can be shaped, formed, modified, and functionalized in almost infinite combinations. This article explores how two types of material demonstrators can contribute to bridging the lab-to-market gap. Some of the methods that exist for closing the lab-to-market gap are identified, and how material demonstrators can assist in achieving this goal is exemplified with biobased packaging materials. We present these findings from the point of view of research, development, and innovation (RDI) practitioners.

Methods

We performed a selective literature review to provide a context for how narrowing the lab-to-market gap is approached in the management literature. We scanned the literature for innovation management, creativity management and elements of design thinking addressing the research-to-market gap. We then performed a conventional content analysis (Hsieh & Shannon, 2005) to identify factors stated as important to narrowing the lab-to-market gap. The inductive category development method (Mayring, 2014) resulted in nine potential roles of material demonstrators.
Results. The 9 Material Demonstrator Roles for Bridging the Lab-To-Market Gap

Generating and expressing new ideas is an important first step in innovation (e.g. Mathews, 2010), where a compelling business case is built on telling a story rather than listing technical properties (e.g. Steen et al., 2014; Markham, 2002). While tools and analysis are important, sparking dialogue is crucial (Terwiesch & Ulrich, 2008; Moultrie, 2015; Lindberg et al., 2016) to seeing new connections between technology and markets. Material demonstrators make R&D results more concrete. First-hand experience of a material supports effective decision making and contributes to the design of the user experience (Barati et al., 2019; Karana et al., 2015).

Promoting a shared understanding of technology and demonstrating their key principles (Moultrie, 2015) and feasibility (O'Connor & Veryzer, 2001) are important to establishing new materials on the marketplace. The exploration of material properties (Boren et al., 2012) and tinkering with the material to explore its characteristics (Karana et al., 2015) promote a shared understanding of materials and what they can and cannot do. A shared understanding of technology creates an absorptive capacity to track and evaluate competing and complementary developments outside the organization (Dahlander & Gann, 2010). This shared understanding is often the result of an iterative process.

Discovering and visualizing market value is important for establishing a business case where new materials are used. Market visioning linking technologies and materials to market opportunities (O'Connor & Veryzer, 2001) helps create contexts for thinking about future products. Technology demonstrators assist in showing market feasibility (Moultrie, 2015; Terwiesch & Ulrich, 2008), in inspiring design thinking (Dunne & Martin, 2006), and in building a portfolio of new business ideas and concepts (Hamel, 2000).

Sorting and prioritizing the ideas generated from a shared understanding of materials is about analyzing the ideas you have and choosing the most promising ones to move ahead with. The process can foster better selection of ideas early on and improve attrition decisions (Mathews, 2010) because materials are better linked to market opportunities.

Articulating corporate strategy and building internal support are both enabled by tangible objects that support decisions about which ideas/concepts will go to the next phase of development (Mathews, 2010). Innovation and corporate strategy are highly intertwined as companies often use current strengths to explore future opportunities at the same time as future opportunities can be used to redefine strategy (Terwiesch & Ulrich, 2008). Demonstrators, mock-ups and prototypes facilitate the exploration and evaluation of technology options and their benefits with users (Steen et al., 2014; Moultrie, 2015), helping shape strategy and build internal support of promising ideas.

Articulating the business case for the innovation and building external support are important steps in accelerating commercialization. Design strategies for different phases of technology adoption often require different attributes to be brought forth (Canada et al., 2007).
Early feedback is valuable for better prototyping (O’Connor & Veryzer, 2001) and helps to better articulate the innovation concept and its business case.

**Reducing uncertainty and risk** eases the implementation of a business case. The more radical the innovation, the greater the need to “de-risk” big aspirations (Hamel, 2000). Evidence-based experimentation can quickly test the merits and risks of ideas because something tangible in the hands of potential users can help to understand customer behaviour and open new possibilities that were not apparent before (LaBarre, 2016; Steen et al., 2014).

**Communicating the fit between technology benefits and market needs internally** is a key ability of material demonstrators. Companies that effectively communicate their capabilities internally can eliminate some of the barriers to innovation (Bond & Houston, 2003), formulate strategies, and plan the market introduction of new products more efficiently. Demonstrators can also facilitate dialogue between project teams.

**Communicating the fit between technology benefits and market needs externally** is aided by material demonstrators for communication both within and outside the scientific community (Moultrie, 2015; Lindberg et al., 2016). Tangible material demonstrators enhance the interaction an organization has with its customers and end-users (Canada et al., 2007), but also enable a more productive communication with potential funders and investors.

**Discussion and Examples of Material Demonstrators as Enablers**

Cellulose-based materials can display a wide variety of states, from gels (Benselfelt & Wågberg, 2019; Khan et al., 2016), foams (Erlandsson et al., 2016), films and filaments (Håkansson, 2021) and particles to networks, sheets, and boards. They can be used as stand-alone materials or be part of other materials. Each material can in turn show a wide array of properties from stretchable to rigid, from opaque to translucent or transparent, from fragile to strong, and material properties can be combined in many ways. A material can also be made active, e.g. respond to a change in temperature by changing its shape. Countless possibilities exist when it comes to demonstrating what the material is and what it can do. Many teams are working to demonstrate these possibilities, e.g. the ChemArts collaboration at Aalto University.

Physical products can be thought to bind physical aspects, psychological aspects and design intentions linked to a product’s purpose, users, and other possible intentions (Ashby & Johnson, 2014). A functional product meets technical specifications and one that also has personality also provides emotional delight and aspects of satisfaction in ownership. Material demonstrators are one way to express both how a material performs technologically and how it can contribute to the personality of a product. We defined two types of material demonstrators having different levels of abstraction: abstract and conceptual, which allowed us to show and communicate different aspects of innovation with different audiences. Abstract material dem-
Conceptual demonstrators are presented as technical material samples or swatches Fig. 1 (A,B,C,D). Conceptual demonstrators show a concept that is in between a swatch and a product. Showcasing both the materials and the RDI competence behind them, conceptual demonstrators were produced under the theme “different faces of cellulose” Fig. 1 (E,F,G,H). They were given classical geometric shapes and showed different properties, from soft and translucent to strong, rigid, and opaque. The intention was to show that they could be developed into packaging materials. Demonstrators stemming from technology development represent the technology-driven side of the gap.

We found that the conceptual demonstrators assisted in better formulating the value of the material and the potential benefits to be had. Both abstract and conceptual demonstrators helped spark the dialogue between material researchers and designers in the team. Researchers had a better appreciation of sensory material qualities and designers better understood the RDI process. As they generated first-hand experiences and understanding of the materials, they allowed the team to creatively explore technology-market possibilities and better prepare interactions with potential clients.

The conceptual demonstrators displayed what the material can do in a specific context or application. The technology-driven concept demonstrator Fig. 2 (C), RISE’s Self-expanding Bowl (winner of the Dieline Sustainability Award 2013; winner of the Plastovationer Innovation Award for Bio-based Materials 2013; named one of the pulp and paper industry’s most innovative products 2015 (CEPI, 2015)) “spoke” to a wider audience and created market demand for more knowledge about what other possibilities exist. Ideas were sorted and prioritized, and the demonstrators helped to reduce uncer-
tainty and risks by enabling a dialogue on client expectations. They also helped us articulate possible value chain strategies, thereby contributing to narrowing the lab-to-market gap. They were central to both internal and external communication about new bio-based materials, potential technology benefits, and identifying market needs.

The demonstrators for the active material helped members of the team to better understand the materials and thereby better discuss them internally. They allowed the team to identify developments outside the organization that could potentially impact on potential market developments. They were also used as a basis for discussions with potential partners.

We also worked with market-driven demonstrators to assist a manufacturer in showing the potential use of new cellulose-based materials in packaging applications. Here, materials were designed to replace leather, snakeskin, rigid plastic and flexible plastic. Demonstrators stemming from potential new markets represent the market-driven side of the gap.

Fig. 2 RISE AB. The material is cellulose-based and developed by RISE. Cellulose-based active material as a) abstract (more technology-driven) demonstrators (swatches) of the material before activation b) conceptual demonstrator as self-opening cone before (left) and after (right) activation c) a (more market-driven) conceptual material demonstrator in the context of a self-expanding packaging used when rehydrating dry foods with hot water.
Abstract and conceptual material demonstrators that stemmed from
showcasing technology assisted in generating and expressing new
ideas, promoting shared understanding of technology, discovering
and visualizing potential market value, and communicating the tech-
nology benefits to market needs fit (internal and external). Concept-
tual material demonstrators that stemmed from a desire to address
an identified market need also helped with sorting and prioritizing,
articulating corporate strategy and building internal support, articu-
lating the business case, reducing uncertainty and risk. Not only are
demonstrators of these types very useful for communicating with the
public at large but they can also help focus discussions with potential
partners for specific market applications.

Fig. 3
RISE AB and Stora Enso Oyj. Market-driven cellulose-based conceptual
material demonstrators a) with tomato waste stream to form a leather-like
material used as a skin for paper-based packaging b) glossy film having
a snakeskin pattern for luxury packaging c) rigid box needing no adhesives
d) flexible bag decorated with dried leaves.
Conclusions

The innovation and creativity literature describes many ways to decrease the lab-to-market gap and our analysis led to the identification of nine significant roles material demonstrators can play to help close the lab-to-market gap and accelerate the transition to a biobased circular economy. These are: generating and expressing new ideas; promoting a shared understanding of technology; discovering and visualizing market value; sorting and prioritizing ideas and concepts; articulating corporate strategy and building internal support; articulating the business case; reducing uncertainty and risk; and communicating the fit between technology benefits and market needs both internally (between business units and project teams) and externally to potential clients and funders of R&D. We explored how material demonstrators can accelerate the transition to a circular bioeconomy, and even if the time from idea to market is not known for all our materials, demonstrators are an efficient way to generate insights. They sped up our part, as a research institute, in the commercialization of new materials by allowing better decisions based on a common understanding: the scale-up of production processes from lab to pilot scale was pursued for the most promising materials, defined market analyses were carried out early on, and tech transfer steps were initiated much sooner.

We described how abstract and conceptual material demonstrators impact different aspects of the lab-to-market gap. They can help promote and communicate a tacit understanding of different aspects of materials that can sometimes be difficult to describe in words. We exemplified the demonstrator types with new biobased materials that can be used in packaging applications. The technology-driven demonstrators designed from an RDI perspective allowed us to show physical objects at packaging fairs that sparked insight into potential applications. When working with market-driven demonstrators designed with an industrial manufacturer in mind, the client used the demonstrators to talk to their customers and increase their understanding of what could be feasible in the marketplace, helping to further reduce the lab-to-market gap.

Reducing the lab-to-market gap for new bio-based materials involves coupling technology-driven results with market-driven needs. Abstract and conceptual material demonstrators are useful in doing this in tangible, inspiring ways. They open the doors to development teams building upon each other’s ideas for the next generation materials and to clients “asking for the impossible” because they understand the potential that new materials can have in their applications.

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