Creating University Spin-Offs: A Science-Based Design Perspective*

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Academic entrepreneurship by means of university spin-offs commercializes technological breakthroughs, which may otherwise remain unexploited. However, many universities face difficulties in creating spin-offs. This article adopts a science-based design approach to connect scholarly research with the pragmatics of effectively creating university spin-offs. This approach serves to link the practice of university spin-off creation, via design principles, to the scholarly knowledge in this area. As such, science-based design promotes the interplay between emergent and deliberate design processes. This framework is used to develop a set of design principles that are practice based as well as grounded in the existing body of research on university spin-offs. A case-study of spin-off creation at a Dutch university illustrates the interplay between initial processes characterized by emergent design and the subsequent process that was more deliberate in nature. This case study also suggests there are two fundamentally different phases in building capacity for university spin-off creation. First, an infrastructure for spin-off creation (including a collaborative network of investors, managers and advisors) is developed that then enables support activities to individual spin-off ventures. This study concludes that to build and increase capacity for creating spin-offs, universities should do the following: (1) create university-wide awareness of entrepreneurship opportunities, stimulate the development of entrepreneurial ideas, and subsequently screen entrepreneurs and ideas by programs targeted at students and academic staff; (2) support start-up teams in composing and learning the right mix of venturing skills and knowledge by providing access to advice, coaching, and training; (3) help starters in obtaining access to resources and developing their social capital by creating a collaborative network organization of investors, managers, and advisors; (4) set clear and supportive rules and procedures that regulate the university spin-off process, enhance fair treatment of involved parties, and separate spin-off processes from academic research and teaching; and (5) shape a university culture that reinforces academic entrepreneurship by creating norms and exemplars that motivate entrepreneurial behavior. These and other results of this study illustrate how science-based design can connect scholarly research to the pragmatics of actually creating spin-offs in academic institutions.

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Introduction

University spin-offs such as Lycos and Genentech serve to transform technological breakthroughs from university research, which would probably remain unexploited otherwise. However, some universities generate substantially

higher numbers of spin-offs than others (e.g., Di Gregorio and Shane, 2003; Klofsten and Jones-Evans, 2000; Kondo, 2004). Moreover, university spin-off activity creates several difficulties, such as the potential conflict of interest between commercial and academic work and the risk to university reputation if founders of spin-offs act inappropriately (Bird, Hayward, and Allen, 1993; Shane, 2004; Slaughter and Rhoades, 2004).

Academic entrepreneurship by way of university spin-offs is an emerging field of research focusing on the process of creating, discovering, and exploiting technological opportunities created by university research. More broadly, the field of entrepreneurship is currently searching for a methodology that would fit its research object (e.g., Davidsson, 2004; Sarasvathy, 2004). Shane and Venkataraman (2000) proposed a framework that focuses on explaining and predicting entrepreneurship as a unique set of empirical phenomena. This framework now is an important benchmark in entrepreneurship research (e.g., Davidsson, 2004); this suggests that academic entrepreneurship research is increasingly being modeled after mainstream management research, drawing on causal frameworks, models, and theories. This type of research has brought a growing understanding of university spin-offs including, among others, the role of different technological regimes (Shane, 2004), the selectivity of the incubator model adopted (Clarysse et al., 2005), the role of the technology transfer unit in providing access to resources and support services (Bekkers, Gilsing, and Van der Steen, 2006; Debackere and Veugelers, 2005), and the differential ability of universities to generate start-ups (Di Gregorio and Shane, 2003).

This growing body of literature focuses on spin-offs that have been established already. However, how they got established in the first place tends to remain unaddressed. In this respect, causal explanation and reasoning helps to explain existing artifacts but may be inadequate to understand the creation of such artifacts (Romme, 2003; Sarasvathy, 2001, 2004; Van Aken, 2004). A more integral understanding of the process of creating university spin-offs is therefore still in its infancy (Shane, 2004).

To analyze this process, a science-based design perspective was adopted in this study. Simon (1996) and Sarasvathy (2004) argued that design involves human beings using knowledge to create what should and could be. Science, by contrast, develops knowledge about what already is. In this respect, a science-based design approach connects the emerging body of research to the pragmatic, action-oriented knowledge of practitioners (Romme, 2003; Romme and Endenburg, 2006). To deepen understanding of the process of spin-off creation, this article takes this more pragmatic body of knowledge as its starting point. A case study is presented of how a university infrastructure for the creation of spin-offs was established. The spin-off practices in this case study were, initially, strongly driven by a more pragmatic approach and subsequently were reshaped by insights derived from scholarly knowledge.

BIOGRAPHICAL SKETCHES

Mr. Elco van Burg is a Ph.D. candidate in the Department of Technology Management at Eindhoven University of Technology in the Netherlands. He obtained a B.Sc. and an M.Sc. in industrial engineering and management science within this faculty, and he holds a B.Ed. in theology. He is currently preparing a doctoral dissertation on academic entrepreneurship and therefore studying the creation of university spin-offs at the university and entrepreneurial level.

Dr. Georges Romme is professor of entrepreneurship and innovation at Eindhoven University of Technology in the Netherlands. He currently also is dean of the Department of Technology Management there. He obtained an M.Sc. in economics from Tilburg University and a Ph.D. in business administration from Maastricht University. He previously was on the staff of Maastricht University and Tilburg University. His current research addresses design methodology, innovation, and technology entrepreneurship. Dr. Romme currently serves on the editorial boards of *Organization Studies* and *Organization Science*.

Dr. Victor A. Gilsing is associate professor in the Department of Social Sciences at Tilburg University in the Netherlands. He started his career at Unilever in the field of business-to-business marketing and innovation. Subsequently, he worked five years at the Dutch Ministry of Economic Affairs as a senior policy advisor in the field of innovation policy. Simultaneously, he completed a Ph.D. in 2003 at ERIM (Rotterdam School of Management). Before moving to Tilburg University he was assistant professor at Eindhoven University of Technology for four years. His current research interests are in the field of breakthrough innovations, strategic technology alliances, and corporate entrepreneurship.

Dr. Isabelle M. M. J. Reymen is assistant professor of design processes in the Department of Technology Management at Eindhoven University of Technology in the Netherlands. She obtained a master's in architecture from the Katholieke Universiteit Leuven in Belgium. She completed her Ph.D. at the Stan Ackermans Institute (SAI) of Eindhoven University of Technology. After postdoctoral work at the SAI, she worked as assistant professor of design management in the Department of Construction Management and Engineering at the University of Twente in the Netherlands. In early 2006, she spent a sabbatical leave at Carnegie Mellon University. Her current research interests focus on design methodology and the development of design guidelines for the design of new product development processes, business development processes, and learning processes.

Why Is This Study Important?

This study connects pragmatic knowledge about how to create university spin-offs to scholarly work explaining why certain practices in this field work and others do not. As such, it makes three contributions to the literature. First, the science-based design approach adopted in this article is fundamentally different from design approaches in other work. Previous studies tend to conceive design as either an emergent process (e.g., Garud, Kumaraswamy, and Sambamurthy, 2006; Sarasvathy, 2001) or a deliberate process driven by design principles (e.g., Romme and Endenburg, 2006; Van Aken, 2004). This article explores the initiating role of an emergent process toward a more deliberate one. In other words, the present study focuses on the interplay between emergent and deliberate design and explores how this interplay can serve to develop a cumulative body of knowledge that is relevant for both practitioners and scholars. A second contribution involves the area of application of the science-based design approach: technology commercialization and entrepreneurship in a university setting. This setting clearly differs from earlier applications (e.g., Denyer, Tranfield, and van Aken, 2008; Romme and Endenburg, 2006) and serves to advance theory development regarding university spin-offs (cf. Whetten, 1989). Third, this article provides an in-depth analysis of a specific case. Such an in-depth study may yield new insights that are relevant beyond the local context of this particular university. Moreover, it may deepen understanding of the creative tension between general theories and principles and the specific local contexts in which universities engage in spin-off creation.

This article is structured as follows. First, the methodology of science-based design is defined, and then the case-study method adopted is discussed. The subsequent section describes the case study. Finally, key findings from this case study as well as the merits and limitations of the methodology adopted are discussed.
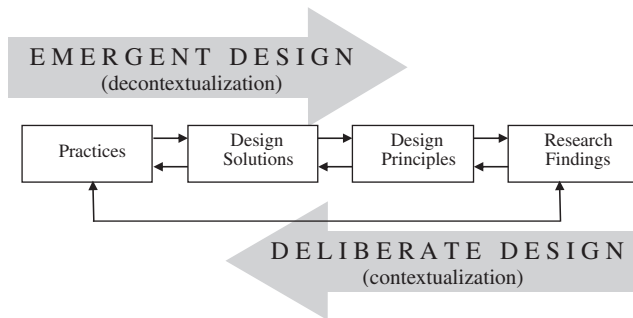
Science-Based Design

This article adopts the science-based design perspective currently emerging in organization research (e.g., Dunbar, Romme, and Starbuck, 2007; Romme, 2003; Van Aken, 2004) and to a lesser extent also in entrepreneurship research (e.g., Sarasvathy, 2003, 2004). The framework proposed here links the scientific knowledge base produced by entrepreneurship researchers to the pragmatic and creative work of practitioners (e.g., entrepreneurs and those advising these entrepreneurs). More in general, it attempts to bridge the gap between managerial practice and academic research (cf. Karniouchina, Victorino, and Verma, 2006).

Following Romme and Endenburg (2006), these epistemically rather different "worlds" are linked by means of design principles. One way to apply this core idea involves using principles grounded in research to create (i.e., conceptual) solutions to be subsequently tried out and implemented in practice (Romme and Endenburg, 2006). Alternatively, experimentation with new practices and solutions can also serve to derive design principles (cf. Plsek, Bibby, and Whitby, 2007).

Science-based design therefore involves the following two key notions linking practices and research findings (cf. Romme and Endenburg, 2006): design principles and design solutions. Design principles involve a coherent set of normative ideas and propositions, grounded in (e.g., entrepreneurship) research, that serve to design and construct detailed solutions. These principles serve as a "boundary" object between the descriptive and explanatory nature of entrepreneurship research and the prescriptive and pragmatic nature of the design process (Romme and Endenburg, 2006). An individual design principle is typically part of a bundle of principles that is loosely coupled to other bundles of principles (Ethiraj and Levinthal, 2004; McCarthy et al., 2006). In this article, the process of formulating design principles is structured by separately developing principles based on practice (practice-based principles) and principles merely based on scholarly knowledge (research-based principles). The synthesis of these principles results in design principles, which thus draw on both practitioner knowledge and research knowledge (see Method section).

Design solutions are representations of the practices being redesigned with help of the design principles, involving actions in the virtual world of drawings, models, narratives, simulations, and so forth. These virtual solutions are more contextualized than design principles; that is, solutions tend to include elements specific to the local setting. These solutions can be directly tested in practice. Representations of a design may be visual (e.g., a diagram depicting the business model of the start-up), physical (e.g., a prototype of the intended product), narrative (e.g., anecdote illustrating customer value attributed to the product), or

Figure 1. The Research–Design–Development Cycle from a Science-Based Design Perspective

combinations of these different forms of representation (e.g., a three-dimensional [3D] simulation).

In the context of entrepreneurship and innovation, design processes tend to be as much emergent as deliberate in nature (Hargadon and Douglas, 2001). The framework in Figure 1 suggests there are ample opportunities for experimentation (practice) to drive the creation of, for example, design solutions and principles. This more emergent design process arises from what Schön (1987, p. 29) called reflection-in-action: the rethinking that leads to on-the-spot experiments as well as the further thinking "that affects what we do—in the situation at hand and perhaps also in others we shall see as similar to it." Weick (2004) characterized the experience of engaging in emergent design as being thrown into a continuously evolving and ambiguous context. This emergent quality of the research–design–development cycle in Figure 1 is likely to prevail when design principles are nonexistent, underdeveloped, or unknown to practitioners. In a more mature discipline, this cycle is as much emergent as it is deliberate: The emergent dimension serves to respond to and account for the unique and dynamic nature of the local setting, whereas the deliberate dimension serves to build a body of knowledge that cuts across multiple settings. The field of entrepreneurship, and of university spin-offs in particular, still lacks a widely accepted methodology or theoretical framework. Therefore, the deliberate and emergent dimensions of academic entrepreneurship need to interact and converge in building a cumulative body of knowledge and practice.

The two faces of design also reflect the need to decontextualize and contextualize principles and solutions (Figure 1). The process of abstracting solutions and their underlying principles from, for example, a first sample of new ventures processed through a university-based incubator involves decontextualization. Similarly, effectively applying a set of general

principles to, for example, the creation of spin-offs in university X implies adaptation to the institutional and regional setting of this university. Moving from right to left in Figure 1, knowledge therefore becomes increasingly contextualized, also in view of the rapidly diversifying nature of organizational, industrial, technological, regional, and cultural settings (cf. MacCormack and Verganti, 2003; Orlikowski et al., 1995; Rousseau and Fried, 2001).

Science-based design can also be understood in terms of the interplay between causal and effectual reasoning (cf. Sarasvathy, 2001). The scholarly body of research findings largely draws on causal propositions and empirical studies testing these propositions. By definition, these studies focus on existing artifacts: for example, spin-off firms generated by a sample of universities in the past 10 years. By contrast, the experimentation and implementation stage in Figure 1 largely draws on effectual logic that is inherently creative. For example, the attempt to create a technology-based firm heavily draws on resources such as personal skills, patented technology, and social as well as professional networks (Sarasvathy, 2001; Shane, 2004). Using these resources, the entrepreneur imagines and tries out possible effects that can be created with them.

Method

The case study in this article serves to illustrate both emergent and deliberate design dimensions and, in particular, the pivotal role of design principles in the interplay between both dimensions. The case study involves the creation and implementation of an infrastructure for generating and facilitating spin-offs at a Dutch university of technology. The study draws on data collected in the period 2005–2007. The data were gathered in two different roles. One of the authors of this article (Romme) was involved as one of the key agents in the redesign and implementation processes (cf. participant-observer data). The other authors performed semistructured interviews and collected documentary data from the usual outsider perspective. The interviews were transcribed, were checked with the interviewees, and were coded according to the procedure outlined by Strauss and Corbin (1990). Interviewees involved a large number of entrepreneurs involved in spin-offs, several managers of the spin-off support unit, two start-up advisors, an intellectual property (IP) advisor, and several entrepreneurship professors. In total, 25 interviews were conducted.

The case-study approach in this article is a clinical rather than descriptive one. The clinical nature of the case study arises from its dual purpose to improve the spin-off performance of the incumbent university as well as to analyze and understand the underlying processes in this case. In tracking the deliberate and emergent design dimensions, three steps were taken to identify, create, and use design principles.

First, so-called practice-based principles were developed by converting the largely tacit knowledge of key agents in university spin-off creation into explicit principles (cf. Plsek et al., 2007). Second, principles are derived from a review of the literature; these research-based principles then serve to understand (and possibly improve) practices and solutions already in place as well as create entirely new solutions (cf. Romme and Endenburg, 2006). Third, the practice-based and research-based principles are synthesized in a set of design principles—defined as principles that are tested in practice as well as grounded in the existing body of research (Romme, 2003; Van Aken, 2004).

The practice-based principles are derived from the data by means of a careful coding and reduction process (Strauss and Corbin, 1990). The first involves coding all different practices and experiences that starters and support advisors reported and those that were described in key documents. Next, the coded practices were clustered and reduced to a small number of categories. For each category, crucial elements of the solutions and any common denominators are identified. Finally, for each of the practice-based principles the different experiences of support staff and entrepreneurs are listed.

Research-based principles were derived by means of a systematic literature review that draws on a qualitative metasynthesis approach (Denyer and Tranfield, 2006; Tranfield, Denyer, and Smart, 2003; Tranfield et al., 2004). The domain of this review was defined in terms of all research in the area of university spin-offs. The purpose of the review is to derive normative (general) principles rather than to provide a comprehensive overview. Therefore, the review protocol takes several existing literature reviews as a starting point, complemented by research not included in these reviews. Three recent literature reviews were identified: Shane (2004), Djokovic and Souitaris (2006), and O'Shea et al. (2004). The findings from these three reviews were synthesized in a number of key concepts and a preliminary set of principles. The latter result was compared and extended with about 15 publications and working papers (not used in the three previously published literature reviews). Subsequently, this set of research-based principles was linked to any general theories that explain the key mechanisms addressed by these principles (cf. Denyer, Tranfield, and van Aken, 2008; Pawson, 2001). Because some of the empirical findings regarding university spin-offs still lack theoretical explanation, the present study also explored other related literatures.

Finally, a set of design principles was composed by confronting and comparing the list of practice-based principles with the list of research-based principles.

Case Study

This section starts with a description of several key events and issues in building capacity for spin-off creation at Eindhoven University of Technology (TU/e) in the Netherlands. Subsequently, the focus is on how two key practices emerged, and the underlying practice-based principles are explored. Then the article turns to how a more deliberate approach, drawing on research-based principles, served to redesign these solutions. The constraints of a single article imply that the practice-based and research-based principles cannot be discussed in detail, but a complete overview of both sets of principles is available on request from the authors. The resulting design principles, synthesized from the practice-based and research-based principles, are discussed later in this section. One potential redesign solution is discussed in more detail. Finally, the set of design principles, resulting from a synthesis of the two sets of principles, is presented.

A university spin-off is "a new company founded to exploit a piece of intellectual property created in an academic institution" (Shane, 2004, p. 4). University spin-offs therefore are a subset of all start-up companies created by students and employees of universities. As such, this definition focuses on the opportunities (based on intellectual property of a university) exploited by new business start-ups rather than on the business founders themselves. The IP exploited by university spin-offs typically involves patented inventions; other spin-offs draw on copyright protection.

Key Events

Until the late 1990s TU/e was strongly focused on applied technology research and education, with strong linkages to several multinational firms in

high-tech industries in the region. TU/e therefore excelled in commercializing some of its technological inventions by means of selling or licensing these inventions to established firms. As a result, many technologies and their potential applications remained unexploited—in particular, those that were not relevant or too immature for the multinational firms the university typically partnered with.

With the appointment of a new chairman of the board in 2002, TU/e's top management decided to change this situation by investing in the creation of an infrastructure that would serve to commercialize key inventions by spinning off new technology ventures. An external professional was hired to set up a spin-off support unit (called InnovationLab) involving start-up advisors and IP professionals. The staff of the spin-off support unit initiated the creation and implementation of a number of key solutions, including the following:

- An undergraduate minor program in entrepreneurship was created and made available from the management school of TU/e (as of 2005). This minor program is now one of the two most popular minors at TU/e.
- A protocol for transferring IP to spin-off firms and distributing revenues among the internal stakeholders (i.e., inventor, research group, university, and entrepreneur) was created in view of the first set of experiments in starting up technology firms (in 2003–2004), involving a high level of anxiety among university representatives, inventors, student entrepreneurs, and investors about revenues distribution. This protocol was developed to create transparency about key standards in the process while maintaining sufficient flexibility in negotiating tailor-made deals about the transfer of IP to spin-offs.
- At the level of all M.Sc. programs, a so-called Technology Entrepreneurship certificate program was tested and implemented.
- A regional network, involving eight organizations, was created to pool resources and to provide access to each others' contacts and resources.

The last two design solutions are discussed in more detail in the remainder of this section.

Until 2005 the experiments with these design solutions were self-contained, in the sense that they were driven by a local search for ideas, benchmarks, and so forth. In other words, the initial stages of the design process were largely emergent in nature (cf. Figure 1).

In summer 2005, a research team came on board and engaged in studying the design and practice of spin-off creation at TU/e; this included a sustained effort to develop design principles grounded in research findings to assess and improve the solutions already in place as well as construct new solutions. Since 2005 the process thus evolved as a more balanced interplay between emergent and deliberate design.

Technology Entrepreneurship Program

The first idea for a university-wide entrepreneurship program for master's students arose from an experiment set up by a professor in chemical technology, who formerly worked in the lab of a multinational firm: "Over there, I got infected by the high tech entrepreneurial attitude: the combination of research into technology and the attempt to commercialize this research. This is a research mentality of not just doing funny things in the lab, but also bringing them to the market." In 2003, this professor collaborated with a visiting professor from Brown University in the United States, and they decided to experiment with Brown University's engineering entrepreneurship program. They formed three teams with students from both the management and chemistry schools; the two initiators and an entrepreneurship professor supervised these teams. The teams conducted applied research on a patented technological invention from the chemistry school's lab. For example, in one of the teams a chemistry student worked on a final graduation (M.Sc.) project in which an application of the technology was prototyped in the chemistry lab, whereas the management student did his M.Sc. final project on the market, strategic and financial approach toward commercializing this application; together, these two students wrote a business plan for the new venture. Two team projects failed to generate a valid business proposition, but the third team was able to develop a successful spin-off. This venture attracted its first major clients and recently built its first plant.

This initial experiment motivated the spin-off support unit to develop a university-wide program along the same lines. The program was further developed, renamed, and embedded in the management school. Compared with the pilot developed in the chemistry school, the program was further developed in terms of an on-line self-assessment system; a contracting stage to align the perceptions of inventor, university, and (student) entrepreneurs; several courses offered by the management school; a master class in entrepreneurial

skills; and a coaching and supervision system. An important aspect of the redesigned program is that students can obtain the certificate in technology entrepreneurship (TE) by completing their individual final projects and the educational components of the program, even when the effort to start up a new firm fails.

These adaptations and extensions of the initial pilot were motivated and constructed with help of principles derived from research on university spin-offs and entrepreneurship education. In this respect, the TE program links entrepreneurial intentions to explorative activities to set up and realize a venture. Several scholars report a positive effect of entrepreneurship education on intentions to create ventures and spin-offs (e.g., Peterman and Kennedy, 2003; Vesper and Gartner, 1997). However, the challenge is to move from intentional to actual, nascent entrepreneurship because there is a gap, or at least a time lag, between intention and action (Souitaris, Zerbinati, and Al Laham, 2007). Nascent entrepreneurs are people who actually are performing activities to establish a company—for example, by developing prototypes, acquiring personal commitments, searching for financial support, and contacting clients (cf. Lichtenstein et al., 2007). Souitaris et al. (2007) found evidence that entrepreneurship programs that include teaching, business-planning, interaction with practice, and university support enhance students' entrepreneurial intentions and their propensity of being nascent. The TE program at TU/e attempts, and in certain cases succeeds, to bring students from being intentional entrepreneurs to become nascent entrepreneurs or even to actually found a new firm. Typically, the new firm is actually founded after graduation, so the program primarily deals with the nascent stage.

Since the formal start of the university-wide program in TE in 2004, 18 projects have been kicked off with 28 students involved. In the meantime, three projects have produced a spin-off firm. Eight projects were completed, but without starting a spin-off; that is, all students involved completed their M.Sc. degree and obtained the TE certificate, but the process of writing a business plan led the participants to conclude that the intended business is not yet feasible. The remainder of the 18 projects are still running.

In case of the aborted attempts to generate spin-offs, the present study's interview data suggest that in most cases the technology was still too immature to be commercialized. Moreover, the students aborting these start-up projects did not want to invest in further work on start-ups with a highly uncertain payback (period). Overall, the program has produced several successful technology spin-offs in a relatively short period, and in the other cases, the program has created graduates with valuable entrepreneurial experience.

Incubator Network

In 2003, TU/e's spin-off support unit set up a regional incubator network. In this network, eight regional organizations work together to support start-ups. Involved are three regional development organizations, a local bank, the incubator of a multinational firm (Philips), an applied research organization (TNO), an undergraduate college, and TU/e. The incubator network was created to pool resources as well as to provide access to each others' contacts, expertise, and resources.

Every two weeks, representatives of all eight organizations meet to discuss ideas, plans, and presentations by would-be entrepreneurs—including students or staff from TU/e. In these meetings, people get direct feedback on their ideas and plans, and the representatives from the eight organizations are invited to explore how their networks and contacts can contribute to the proposed new ventures. The group of representatives also frequently provides starters with experienced coaches. For example, one of these representatives explains, "It gives them possibilities at Philips Research and at TNO. The first time a starter needs something, they can use equipment from these research sites for free or with a discount. So, they can use such equipment to see if their concept 'works' or not."

Around the eight formal partners in the incubator network, there are another 20 firms (e.g., lawyers, tax consultants, recruitment and selection firms) that are committed to help starters with advice or services at reduced fees. In addition, the incubator network has created a fund to directly support starters, and it frequently provides starters access to banks, informal investors, and venture capital firms. This fund helps to make the first investments to develop a prototype as a proof of principle, thus bridging the first stages of the "valley of death" from invention to innovation (Auerswald and Branscomb, 2003). Each year, about 75 students from TU/e ask for assistance from the incubator network, and if they are selected they get access to the resources and services of the network. Annually, about 50 applications are granted.

The interview data collected suggest that the incubator network helps starters in developing their own networks as well as in acquiring financial and other resources. For most starters, the single most valuable aspect is that it helps them build relationships with investors, coaches, other starters, potential clients, and other support organizations. In addition, the incubator network also creates reputation value for the starter (e.g., in approaching and dealing with potential clients, investors, and the tax office).

The incubator network was pioneered by TU/e's spin-off support unit. When a research team (the authors of this article) came on board in 2005, it started identifying key opportunities for further development of the network. A core issue here was the development of the personal and professional networks of the participating starter-entrepreneurs in the incubator network. The incubator network at that stage merely served to refer starters to helpful contacts rather than to motivate and facilitate starters to build interpersonal relationships.

Both network and entrepreneurship researchers, however, have emphasized the importance of these interpersonal ties—especially those with relevant people outside academia (Nicolaou and Birley, 2003b; Ring and Van de Ven, 1994; Shane, 2004). In this respect, people involved in university spin-offs start out with interpersonal networks that are primarily academic in nature; if they do not invest in ties with the industrial and financial world, industry representatives and investors are likely to consider the spin-off as an academic venture rather than a real company (e.g., Bekkers, Gilsing, and Van der Steen, 2006; Vohora, Wright, and Lockett, 2004). Drawing on social capital theory, Nicolaou and Birley (2003a) argued that networks around spin-offs have four potential benefits. First, networks augment the opportunity identification process, as it enhances the entrepreneurs' recognition capabilities because entrepreneurs can discover the opportunity through the right personal contact. Second, networks provide access to loci of resources, for example to acquire access to capital, as is offered in the TU/e case by the cooperation with the bank in the incubator network. Third, networks engender timing advantages, because the entrepreneur is able to know and use opportunities quicker. Fourth, a network such as the incubator network constitutes a source of trust and credibility with regard to the start-up company, because these network partners are credible organizations that back the start-up (Nicolaou and Birley, 2003a). Because of these benefits, the establishment of a network is closely related to the success of the start-up (Hackett and Dilts, 2004).

Therefore, the incubator network decided to invest more resources and effort in recurrent events intended to motivate and facilitate the development of interpersonal ties. Within the incubator network program, starters can now attend a variety of network events, including so-called Meet & Match sessions where starters pitch their propositions to investors and representatives from industry. These sessions are perceived to be very useful for skill development, feedback received, and opportunities to develop new interpersonal ties. For example, one of the starters evaluated the last Meet & Match event he attended: "Last time, there was a Meet & Match. Starters and business sit down together. We got three useful contacts out of it. That's the way we get our first clients."

Synthesis into Design Principles

To illustrate the process of developing design principles, the construction of one principle is discussed here. First, a practice-based principle is extracted from practitioners' experiences, and subsequently a related principle is derived from research findings using a metasynthesis approach. Table 1 provides an overview of the set of design principles arising from this study.

Many of the interviewees emphasized that awareness of opportunities to become an entrepreneur is an important precondition of eventually and successfully starting a spin-off company. For example, spin-off support professionals observed that many would-be entrepreneurs contact these professionals relatively late because they were not aware of the facilities and resources available within the university. To increase awareness among students and staff, the incubator support unit increased the exposure of entrepreneurship courses, appointed scouts in each academic department, trained staff in commercializing research findings, and cultivated entrepreneurial role models. These measures have had major effects. A start-up advisor explained, "In the past, one was not allowed to talk about entrepreneurship. But now, a number of people is triggered by the attention to it, and says, 'That's funny, I will do it.'" These findings led to the following practice-based principle:

P1: Make potential entrepreneurs (e.g., students, Ph.D. students, staff members) aware of opportunities to start a venture based on a research finding.

Table 1. Synthesis of Practice and Research in Terms of Design Principles

Aspects of Practices/Solutions in Case Study	To build and increase capacity for creating spin-offs, universities should design and implement practices that:	Underlying Theories
Involve start-up advisors in entrepreneurship education. Enable students to combine their thesis work with the preparations for starting a venture. Early in their study, give students information about entrepreneurial opportunities. Appoint a contact person within each school. Offer newly hired employees a training regarding technology commercialization. Screen and select potential entrepreneurs based on their potential.	1. Create university-wide awareness of entrepreneurship opportunities, stimulate the development of entrepreneurial ideas, and subsequently screen entrepreneurs and ideas by programs targeted at students and academic staff.	Opportunity identification (Djokovic and Souitaris, 2006; Shane, 2000, 2004) Knowledge theories (Djokovic and Souitaris, 2006)
Create student (start-up) teams from multiple disciplines. Advise starters with regard to, for example, their business plan, facilities, finance, subsidy requests, start-up team, and patenting. Start-up advisors need to be creative in finding solutions and approach starters in a personalized way. Create start-up teams with the right mix of skills by training or by adding people to the team. Build a pool of entrepreneur coaches who are willing to advice starters from practice. Create a board of commissioners around each start-up. Provide advice regarding the acquisition of grants.	2. Support start-up teams in composing and learning the right mix of venturing skills and knowledge by providing access to advice, coaching, and training.	Resource-based theory (O'Shea et al., 2005) Organizational development theories (Clarysse et al., 2005)
Create arrangements for starters to use university labs and other resources. Provide office space with the possibility to use different services. Create flexible contracts and good conditions, but market prices. Enable starters to use the academic network of the university. Establish a network around the support organization of investors, industry contacts, and financers. Set up regular meetings with the core network partners to discuss, for example, start-up proposals. Cultivate the prestige of the university to gain credibility. Organize networking events with starters. Create funds to support students and starters in the orientation stage. Create ways to obtain significant amounts of funding. Permit equity investments of the university in spin-offs in exchange for payments. Create a structure that enables the university to have participations in spin-offs.	3. Help starters in obtaining access to resources and developing their social capital by creating a collaborative network organization of investors, managers, and advisors.	Social capital theory (Nicolaou and Birley, 2003b) Organizational development theories (Clarysse et al., 2005)
Establish fair rules regarding the internal distribution of revenues from the exploitation of inventions. Create procedures to manage and assess the balance between academia and business. Allow staff to take equity in spin-offs.	4. Set clear and supportive rules and procedures that regulate the university spin-off process, enhance fair treatment of involved parties, and separate spin-off processes from academic research and teaching.	Organizational justice theory (not yet applied) (e.g., Hosmer and Kiewitz, 2005) Complexity theory (not yet applied) (e.g., Cilliers, 1998; Kauffman, 1995)
Create commitment at faculty boards. Cultivate successful entrepreneurs as role models. Establish a clear and accountable structure, with high commitment of the university board. Establish an organization that operates in a businesslike manner.	5. Shape a university culture that reinforces academic entrepreneurship by creating norms and exemplars that motivate entrepreneurial behavior.	Organizational culture theories (not yet applied) (e.g., Schein, 1992)

In the literature several programs and practices dealing with the incubation, selection, and support of proposed ventures are studied and assessed. First, programs such as business plan competitions are important to provide inflow of potential academic entrepreneurs into subsequent stages of the incubation process (Djokovic and Souitaris, 2006; Fini, Grimaldi, and Sobrero, 2006). The selection of these potential entrepreneurs and their ideas depends on the goals of the spin-off support (Clarysse et al., 2005). In a well-designed support infrastructure, these goals also determine the degree and kind of support. This support by skilled people (Mowery et al., 2004) should at least help with the development of appropriately composed venturing teams, especially with regard to knowledge and skills (Djokovic and Souitaris, 2006; Shane, 2004; Vohora, Wright, and Lockett, 2004). Team development support can involve creating other team compositions, development of skills, or network development. These research findings are captured in the following research-based principle:

P2: Screen technologies and ideas for new ventures, and subsequently provide start-ups with advice and coaching from skilled people.

In addition, the study listed theories describing the generative processes underlying this principle: Opportunity identification theory provides a theoretical framework that explains the role of programs targeting the emergence of entrepreneurial ideas (Ardichvili, Cardozo, and Ray, 2003; Djokovic and Souitaris, 2006; Shane, 2000, 2004); moreover, knowledge theory explains how previous and current training, coaching, and advice processes affect the entrepreneurial dispositions and intentions of students and staff (Djokovic and Souitaris, 2006).

A comparison of the practice-based and research-based principles previously described results in the following observations. The practice-based principle involves information provision, visible support, and scouting potential entrepreneurs. The research-based principle deals with emergence of ideas, goals for spin-off creation, advice, coaching, and training. Both principles focus on the idea generation phase of the spin-off process; in addition, the research-based principle deals with advice, coaching, and training. Because other practice-based and research-based principles also consider the advice, coaching, and training aspects, these were included in another design principle. This results in the first design principle listed in Table 1.

The process of comparing and synthesizing the two sets of principles leads to the following set of design principles. To build and increase capacity for creating spin-offs, universities should design and implement practices that do the following:

1. Create university-wide awareness of entrepreneurship opportunities, stimulate the development of entrepreneurial ideas, and subsequently screen entrepreneurs and ideas by programs targeted at students and academic staff
2. Support start-up teams in composing and learning the right mix of venturing skills and knowledge by providing access to advice, coaching, and training
3. Help starters in obtaining access to resources and developing their social capital by creating a collaborative network organization of investors, managers, and advisors
4. Set clear and supportive rules and procedures that regulate the university spin-off process, enhance fair treatment of involved parties, and separate spin-off processes from academic research and teaching
5. Shape a university culture that reinforces academic entrepreneurship by creating norms and exemplars that motivate entrepreneurial behavior

Table 1 links this set of design principles to aspects of practices created at TU/e as well as to the theories that explain the processes in these principles.

These design principles serve to reflect on the comprehensiveness of previous research and theory development and to explore to what extent the practice of university spin-off generation is described and explained in scholarly work. In this respect, Table 1 illustrates that some design principles are not yet incorporated in literature about university spin-offs. A major example is Principle 4. This principle and some of the practices observed at the TU/e case are not yet grounded in any theoretical frameworks. Theories adopted from the complexity science and organizational justice literatures may provide such a deeper understanding of the generative processes behind this design principle. The complexity science literature provides a framework for understanding and managing universities as complex adaptive systems (Cilliers, 1998) that wish to perform academically as well as entrepreneurially. For example, Eisenhardt and Sull (2001) suggested that a set of well-chosen simple rules can shape a wide range of resilient and productive processes. That is, when organizing becomes increasingly complicated and dynamic, its

design should become simpler and easier to modify (cf. Eisenhardt and Sull, 2001). In addition, the organizational justice literature may serve to develop a theory of the effectiveness and fairness of rules and procedures for university spin-off processes (e.g., Hosmer and Kiewitz, 2005).

Spin-Off Creation: Results and Future Challenges

The TU/e case illustrates how a more emergent design process, driven by practitioners, can be extended and enhanced by means of a more deliberate approach. The two practices previously described—the TE program and the incubator network—were pioneered by practitioners and subsequently fine-tuned with help of a research-driven perspective. Table 2 provides an overview of the annual number of spin-offs, exploiting intellectual property developed at TU/e, over a 10-year period. The spin-offs in 2005 and 2006 include three spin-offs developed from the TE program. The trend in Table 1 suggests that TU/e is on track in terms of increasing its ability to commercialize intellectual property by means of spin-offs.

However, the design principles in Table 1 also expose blind spots and therefore major areas of improvement, as illustrated in the remainder of this section. Many interviewees observed that TU/e still misses an entrepreneurial culture. Academic staff tend to focus on academic research and education; technology transfer and especially spin-off formation is rather foreign to most academics in this university. This is therefore a major barrier to spin-off creation. For example, the coordinator of the TE program observed, "Students experience resistance. They say, 'I'm allocated to a faculty subdepartment and I would like to combine my graduation project with exploring the start of a spin-off in the Technology Entrepre-

Table 2. Number of IP-Based Spin-Offs from Eindhoven University of Technology, 1997–2006

Year	IP-Based Spin-Offs
1997	1
1998	0
1999	0
2000	5
2001	3
2002	2
2003	0
2004	8
2005	7
2006	5

neurship program. However, my supervisor from the subdepartment is not convinced, because he has his own agenda and says: I'd like that you do this research, because that's what I'm involved in.' That clashes sometimes and causes that some students abandon the program. These students were quite enthusiastic, but when they go back to the research group they're graduating in, they may talk them out of it."

Table 1 indeed implies that TU/e has hardly developed solutions and practices implied by the fifth design principle regarding an entrepreneurial culture in this table. Evidently, this is an enormous challenge. More than any other principle in Table 1, the creation of an entrepreneurial culture requires a university-wide effort and long-term commitment by all stakeholders involved. Once such a university culture starts to develop, it helps to increase the awareness among scholars and students of opportunities to commercialize inventions developed in the university (Bird and Allen, 1989; Djokovic and Souitaris, 2006). Shaping such a culture takes much time, because both scholars and administrators need to adopt altered values (Clark, 1998; Debackere and Veugelers, 2005).

Some initial measures to create conditions for an entrepreneurial culture to arise have recently been adopted at TU/e including—for example, the cultivation of successful entrepreneurs as role models (Table 1). Important other changes, such as adjusting the career–reward structure toward explicit incentives and rewards for entrepreneurial effort and performance (Siegel et al., 2004), have not been implemented at TU/e. At most universities the key incentives for academic scholars motivate them to focus on publications rather than on entrepreneurial activity (ibid.). Thus, many scholars in TU/e and elsewhere tend to believe that engaging in entrepreneurial activities with highly uncertain outcomes will undermine their academic career.

Therefore, it is important to develop clear standards and rewards that specify how and why academic staff can engage in entrepreneurial activities: for example, by offering leaves of absence for inventors who wish to found companies (Shane, 2004); temporarily freezing the tenure clock (Fini, Grimaldi, and Sobrero, 2006); and individual performance evaluation systems that are likely to increase the respectability of entrepreneurship (Kirby, 2006; O'Shea et al., 2004; Vohora, Wright, and Lockett, 2004). Moreover, Slaughter and Rhoades (2004) argued that faculty's entrepreneurial engagement may undercut

their commitment to teaching and services, particularly those irrelevant to the pursuit of patents and firm start-ups. Strong incentives for entrepreneurial behavior may also shift attention from research areas with few patenting opportunities toward those with more patenting potential (Mustar et al., 2006). In addition, the patenting of university technologies, as an important basis for spin-offs, may prevent a free flow of knowledge within the academic world (cf. the studies reviewed by Shane, 2004). Creating a balance between incentives for research and teaching and those for entrepreneurship is therefore a delicate matter. Regarding the latter balance, this article acknowledges that universities should not engage in university spin-offs because of the expected financial benefits; there are hardly any, as the evidence collected by Shane (2004) suggests. If a university commits to entrepreneurship and incubation of new firms, they should do so to commercialize ideas and technologies developed in this university into applications with huge potential benefits to society. The side effect, intended or not, is that the reputation and prestige of the incumbent university will very likely benefit.

Discussion and Conclusion

This article proposes a science-based design approach to the creation of university spin-offs. This approach was applied in developing a spin-off support infrastructure at a Dutch university of technology. The latter case study illustrates some of the benefits as well as problems of science-based design.

Major Research Results

As argued earlier, science-based design connects the body of scientific knowledge to the pragmatic, action-oriented knowledge of practitioners. To develop deeper understanding of the spin-off creation process, this study started with codifying practitioners' knowledge. As such, the article discussed how an emergent design approach developed at a particular university enhances the ability to create more university spin-offs. Once a number of components of the infrastructure were in place at this university, a more deliberate design process served to extend and improve the existing practices and solutions.

In this respect, two important issues arise. First, a largely emergent design process induced the process, not a deliberate design process per se. This counters the prevailing view in the literature on the dominant role of a deliberate design approach, which tends to ignore the role of emergent processes. By contrast, the role of deliberate design in the TU/e case was mainly to fine-tune and improve the solutions created by pioneering practitioners.

Second, the TU/e case suggests two fundamentally different phases in the design process, with one phase involving the creation of an infrastructure for spin-off creation that creates conditions for a subsequent phase focusing on spin-off support. This differentiation into phases has been largely ignored in the university spin-off literature, which focuses on spin-off formation in terms of hands-on support but has overlooked the role of an important phase preceding this. Thus, the literature tends to implicitly assume a certain university-wide infrastructure being in place and in operation. In this respect, the case study in the previous section suggests that it is critical to embed spin-off incubation in educational activities as well as network ties with industry, investors and other external stakeholders. These preincubation activities are likely to increase the inflow of people, ideas and resources in the process of actually creating ventures that may result in successful spin-offs. With the design and implementation of pre-incubation systems and processes, any investment in direct support to spin-offs is more likely to pay off.

Theoretical and Managerial Implications

This study has several implications. The case study suggests that emergent design processes can be essential in getting started as well as in experimenting with potential solutions. It also shows that a deliberate design approach can assure that the process stays on track by safeguarding and improving it, particularly by codifying design solutions and principles. The emergent and deliberate approaches therefore complement one another. The emergent design process underlines the complexity of the processual side of university spin-off creation, whereas deliberate design pushes an emergent process to go beyond its informal and at times chaotic ways of operating. Therefore, the confrontation and interaction of the two approaches helps to build a cumulative body of knowledge and practice, as an essential step to a common theoretical framework in the field of entrepreneurship and spin-off creation by universities.

More specifically, the set of design principles resulting from this study provides a benchmark for any future work that deliberately links efforts to increase

spin-off creation capacity to scholarly research in this area. The principles described in Table 1 are preliminary in nature, in the sense that other case studies will adapt and extend these results. Moreover, these five design principles refer to basic conditions and practices (cf. minimum requirements) that need to be created to build some capacity for spin-off creation. That is, they apply to universities that experience major difficulties in creating spin-offs rather than those already performing effectively in this area.

Limitations and Future Research Directions

A limitation of the approach taken in this article is its restriction to a single case. The single-case-study approach provides opportunities to develop an in-depth understanding of the process of spin-off formation at a particular university, but it limits the generalizability of the study's findings. In particular, it is difficult to generalize findings to other disciplines and university types. Previous studies imply that spin-offs mainly originate from the sciences instead of the arts and the social sciences; within the sciences most start-ups tend to arise from the life sciences—for example, biotechnology, pharmacy, and medical devices (e.g., Meyer, 2003; Shane, 2004). Thus, as TU/e is a university specializing in the sciences and technology, the principles developed in this article may not equally apply to other university types and research areas.

Moreover, future developments in the institutional context of universities may undermine the findings and principles arising from this study. For example, the findings that produce the design principle regarding supportive rules and procedures (principle 4 in Table 1) assume the IP regime that is currently prevailing in the United States and most other countries in the Western part of the world (e.g., Bayh-Dole Act in the United States and similar regulations elsewhere). If this regime changes significantly, the related design principle will also need to be revised. A completely different IP regime may indeed imply that universities can develop lean procedures and systems that avoid additional decision-making layers to speed up the technology commercialization process and shorten cycle time (Litan, Mitchell, and Reedy, 2007).

Overall, this study produces a number of new insights that carry relevance beyond the context of the case studied. Any university that wishes to stimulate spin-off activity needs to start by creating an infrastructure for preincubation as well as support of spin-offs. The TU/e case illustrates how this can be done.

The experiences and resulting design principles can serve as a basis for other universities wishing to engage in university spin-off creation as well as for future research in this area.

The case study also produced two design principles that need further development. The design principle regarding supportive rules and procedures is not yet grounded in the university spin-off literature. The previous section outlines several theoretical frameworks that can help to develop a deeper understanding of the role of rules and procedures regarding spin-off formation by universities. The design principle regarding entrepreneurial culture implies a major deficiency in the current practices of spin-off formation at TU/e. These findings suggest that building an entrepreneurial culture constitutes a challenging agenda for future studies, particularly those that draw on theories not yet used in the university spin-off literature.

A specific challenge is to decontextualize some of the issues arising from the TU/e case and to adapt them in such a way that they fit with another institutional context. In this respect, most previous studies suggest a general logic regarding the process of spin-off formation. The approach chosen in this study implies that research findings following this general logic have to be adapted and contextualized in view of the local institutional contingencies (cf. Figure 1). When done effectively, two potential risks in the complex process of university spin-off creation can be diminished: getting lost in the potentially overwhelming local complexity of spin-off creation on the one hand and developing too generic theories overlooking local idiosyncrasies on the other hand.

Examining more cases from a science-based design perspective will serve to increase our understanding of the contextual contingency of the design principles explored in this article. The examination of more cases will provide more insight in the relative importance of these principles in different contexts. Future research can also test and adapt the proposed principles by creating and developing solutions for other universities.

Evidently, any set of design principles grounded in practice and research evidence is no guarantee for success. The issues raised by university spin-offs are extremely complex, even when participants have access to a body of knowledge and experience codified in design principles. Moreover, any body of knowledge will continue to evolve as a result of new empirical findings as well as experiences obtained in new settings.

In sum, science-based design provides a relatively new perspective on researching and practicing the creation of university spin-offs. This perspective suggests that studying and practicing academic entrepreneurship are two sides of the same future coin, involving a coherent body of explanatory and normative knowledge in this area.

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