Abstract

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MANAGING LEISURE TIME INVENTION

Abstract

Invention and innovation are central to a firm’s continued development and growth. One source of breakthroughs is “leisure time invention,” defined as invention where the main underlying insight occurs while the employee is away from work. Well-documented examples include 3M Post-it notes, Apple Computer, and Starbucks Coffee. Drawing on research on knowledge recombination, we theorize how and why leisure time invention is different from work time invention. We develop a comprehensive theoretical model of the nature and consequences of leisure time invention compared with work time invention, and present our findings in terms of testable propositions that can guide future empirical research. We propose that leisure time invention, compared with work time invention, is likely to produce novelty for organizations due to high knowledge distance, idiosyncrasy, and serendipity in the idea creation process. We also argue that leisure time invention is harder to convert usable concepts internally in the firm, compared with work time invention, since it produces higher information asymmetry, is more difficult for managers to evaluate as regards its importance and organizational impact, and is associated with higher transfer costs. Our research advances the understanding of how life outside the organization can affect innovation within the organization.

Keywords: Invention; Innovation; Leisure time; Knowledge combination; Novelty
JEL classification: O30; O31; O32
1 Introduction

Invention and innovation are central to a firm’s continued development and growth. A key challenge for managers is to identify, reward, and effectively implement the inventive insights made by their employees, while minimizing the costs of these efforts (including the costs of pursuing worthless ideas). This paper focuses on one aspect of this challenge: how managers can best address the opportunities and problems that arise from “leisure time invention,” defined as invention where the main underlying insight occurs while the employee is away from work. Well-documented examples (taken from Davis, Davis, & Hoisl, 2013) include the inventions of Post-it Notes, the Apple computer, and Starbucks coffee bars (see Table 1).

--- Table 1 about here ---

- **Post-it Notes** (Reid & de Brentani, 2004). 3M chemical engineer Art Fry was seeking a solution for a non-sticky adhesive invented by co-worker Spencer Silver, when he had his leisure time flash of genius, realizing it could be used on the back of a hymnal bookmark. 3M management was initially skeptical, so Fry built a prototype machine in his basement. Eventually, Post-It Notes became one of 3M’s most successful inventions.

- **The Apple computer** (Wozniak, 2006). Steve Wozniak, then at Hewlett Packard, combined his knowledge of computer technology with a key leisure time insight about how to link a keyboard to a TV screen, to cobble together a primitive computer. Wozniak’s bosses at HP were not interested in developing the computer, so he left, and with Steve Jobs, formed Apple.

- **Starbucks coffee bars** (Dyer, Gregersen, & Christensen, 2009). Howard Schultz, director of marketing at Starbucks Coffee Company, which sold whole coffee beans, leaf teas, and spices, was inspired while travelling through Italy to reorient the company to specialize in coffee bars. When management refused, he left; later he returned to realize his vision.

Based on these stories, one might speculate that the creative and organizational processes involved in leisure time invention are different from those for work time invention. Instances where an inventor is away from work – and thereby “freed” from the normal work time pressures – could lead to more unconventional, less path-dependent search processes, possibly sparking the
generation of powerful new ideas. Yet in all three examples above, management was not initially receptive. At 3M, the inventor was eventually (after building a prototype himself, and “selling” the idea to fellow workers) able to persuade management to commercially develop the invention; at Apple, the inventor left HP to set up his own firm; at Starbucks, the inventor left and then returned to reorient the company. This suggests that firms that disregard employee leisure time insights could miss out on important inventions.

The three following stories in Table 1 support the importance of leisure time inventive insights to spur novelty, but illustrate different types of organizational outcomes.

- **LASIK eye surgery (Wynne, 2012).** IBM scientists needed to find a safe way to test their idea of shooting lasers at the human eye to correct myopia. One scientist, Rangaswamy Srinivasen, enjoying a Thanksgiving turkey, was struck by the insight that a turkey bone with a little cartilage would have just the right consistency. Management supported the idea, and the team eventually successfully developed LASIK.

- **Quicken (Taylor and Schroeder 2003).** Scott Cook had started his career in marketing at Proctor & Gamble, and strategic consulting at Bain & Co. One day, at home listening to his wife complain about the difficulties of managing a household budget, he realized he could develop software to address this need. Drawing on earlier workplace experiences and together with software engineer Tom Proulx, he founded Intuit to develop Quicken.

- **Controlled flight (wing warp) (Bereiter 2009).** Orville and Wilbur Wright, owners of a bicycle/printing shop, worked as bicycle mechanics. In their leisure time, they read about the latest technical advances in airplane design. While picnicking in the countryside, they observed how buzzards banked and turned in the air, and suddenly realized that this principle could also enable airplanes to turn safely in the air.

In these instances, the leisure time inventors, respectively: persuaded management to support the idea; drew on earlier job-related knowledge but did not involve previous employers in the development of the invention; and did not worry about convincing management to go ahead, since they owned their company. We were intrigued to investigate these differences further.

While much has been written how organizations can promote workplace invention and innovation in the knowledge management (e.g. Katila & Ahuja, 2002; Rosenkopf & Nerkar,
and creativity literature (Elsbach & Hargadon, 2006), virtually nothing is known about how leisure time insights might contribute to organizational invention and innovation, or what special managerial challenges are involved. Our research question is: *How does leisure time invention differ from work time invention as regards the novelty of the inventive insight, and its conversion into a viable product concept?*

This research gap is surprising. Empirically, there is ample anecdotal evidence about breakthrough innovations which arose from leisure time inventions (see (Davis et al., 2013). Conceptually, scholars have acknowledged that “different people in a firm will to a greater or lesser extent introduce elements of novelty from their outside lives […] [which] is a source of both error and innovation (2000, p. 71) and called for more research on “outside-in influences regarding how and why employees engage in creativity and innovation” (Anderson, Potočnik, & Zhou, 2014, p.27). Theoretically, leisure time should play an eminent role for innovation. Any process of creativity and invention starts with a stimulus (Amabile, 1983; Maggitti, Smith, & Katila, 2013) which is often rooted in the external environment. Since individuals spend more time in leisure activities than at work (OECD, 2009)¹, it should come as no surprise that inventive insight often happens in leisure time and not at work.

To inform our analysis, we draw mainly on the literature on the knowledge combination process, supplemented by relevant work on task problem-solving (e.g. Fleming, 2001; Katila & Ahuja, 2002; Maggitti et al., 2013; Schilling & Green, 2011). Previous research has shown that innovation can be enhanced by exposure to a wide variety of ideas in different technological domains (e.g. Singh & Fleming, 2010), and by drawing on a range of knowledge sources (e.g. Gray & Meister, 2004; Levitt & March, 1988). Yet the ability to learn from and apply external knowledge may be limited by the firm’s own existing knowledge (Nelson & Winter, 1982), and may be costly to integrate (Henderson & Cockburn, 1994; Polanyi, 1966).

Our main contribution to the literature is to show how and why innovation where the key inventive insight occurs during the employee’s leisure time is different from innovation where this insight occurs during work time. Existing research has acknowledged leisure time invention

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¹ According to OECD. 2009. *Society at a glance.* (Figure 2.3), people engage in leisure time activities 21.6% of the day, and paid work 16.5% of the day.
as an important source of innovation, but has not explained the differences between leisure time and work time invention with respect to organizational outcomes (Davis et al., 2013). We develop the argument that leisure time invention, compared with work time invention, involves a different form of knowledge combination, thereby producing different outcomes. We contend that leisure time inventions are more novel than work time inventions, and provide new theoretical explanations – the importance of high knowledge distance, high idiosyncrasy of knowledge, and serendipitous discovery – for these arguments. We also contend that leisure time inventions are harder to convert into usable concepts internally by firms, and theorize that this is due to the comparatively higher degree of asymmetric information, management uncertainty as regards its importance and organizational impact, and transfer costs associated with leisure time invention.

In addition, we contribute to research that has started to investigate how life outside the organization affect life within it. The focus of this literature to date has been to explore how conflicts between work and the employee’s life outside the organization affect job attitudes (e.g. Allen, Herst, Bruck, & Sutton, 2000). With respect to innovation, scholars have investigated how creativity at work affects relationships at home (Harrison & Wagner, 2016). We add to this literature by analyzing how the employee’s leisure time affects the innovativeness of her organization, a topic which has thus far been neglected.

To this end, we develop a comprehensive theoretical model of the nature and consequences of leisure time invention compared with work time invention, incorporating a more systematic approach than currently exists in the literature. We present our findings in the form of testable propositions to guide future empirical research. We structure our arguments by outlining, first, the main existing theory with regard to: the nature of the knowledge combination process (Section 2), the nature of leisure time invention (Section 3), and the nature of the inventive knowledge combination process, which can involve both need-based and solution-based knowledge, as it pertains to leisure time invention (Section 4). On this basis, we generate six propositions comparing the characteristics of leisure time invention and work time invention. Propositions 1, 2 and 3 concern the determinants of the novelty of the invention at the “idea creation stage”; Propositions 4, 5 and 6 concern the initial organizational implementability of the invention at the “idea conversion” stage. Table 1 illustrates how these theoretical concepts may
be applied in relation to six important leisure time inventions that are discussed in the text. We discuss our findings and implications for future research in the final sections of the paper.

2 The knowledge combination process

Knowledge combination and recombination, and the associated search process, play a central role in the invention and innovation process (e.g. Fleming, 2001; Fleming & Sorenson, 2004; Katila & Ahuja, 2002; Laursen & Salter, 2006). Researchers have explored how firms can best coordinate and integrate the different types of specialist knowledge of their individual members to enhance innovation (e.g. Grant, 1996; Nickerson & Zenger, 2004). As Nonaka (1994) writes, innovation may be seen as a continuous process by which the organization both defines and solves problems by converting existing knowledge – drawing on both tacit and explicit knowledge inputs – into new knowledge. Effective knowledge combination and recombination is a strong predictor of innovative performance (Katila & Ahuja, 2002).

Many scholars have shown how creativity is increased when the inventor can draw on more diverse sources of knowledge in different domains (Burt, 2004; Hargadon & Sutton, 1997). The knowledge combination process may involve combining components of technologies in new ways (Nelson & Winter, 1982), or reconfiguring existing technologies (Henderson & Clark, 1990). More recent work has focused on the role of accessing external knowledge sources (Fleming, 2001; Katila & Ahuja, 2002), including engaging inter-personal networks (Owen-Smith & Powell, 2004) and user innovation (Foss, Laursen, & Pedersen, 2010).

Other work has emphasized that to lead to competitive advantage, innovations must also be effectively integrated into the firm’s other activities, which can be costly (Henderson 1994, Arora 1996, Nonaka and Toyama 2003). Key obstacles to the effective integration of external knowledge sourcing, for example, include the problem of path dependency, where, within the firm, results from earlier projects usually form the basis for further projects (Nelson & Winter, 1982), competency traps (Levitt & March, 1988), a lack of absorptive capacity (Cohen & Levinthal, 1990), and the not-invented-here syndrome, where new, external ideas may incur resistance on the part of internal personnel due to the “not invented here” syndrome (Antons & Piller, 2015; Katz & Allen, 1982).
The knowledge combination process leading to invention involves “linking some purpose or need with an effect that can be exploited to satisfy it” (Arthur, 2007, p. 254). The former part of this definition comprises “needs [innovating entities] will face in current or future markets” (Alexy, George, & Salter, 2013, p. 270) and includes knowledge about personally or socially perceived problems and purposes. The latter part relates to solution knowledge about technologies, which are “built around the reliable exploitation of some base phenomenon as envisaged through some principle of use” (Arthur, 2007, p. 278), including knowledge about a physical phenomenon or effect and an operational principle. An operational principle “defines how the parts interact with one another to implement the goal of overall technology” (Murmann & Frenken, 2006, p. 939); it is the functionality provided by the technology (Arthur, 2009) and the means by which a technology fulfills some expressed purpose – some need – personally or socially perceived.” (Arthur, 2007, p. 278).

3 Leisure time invention

Both leisure time and work time invention can involve a combination of need and solution knowledge: 1) a new problem occurs which is combined with an existing solution, or 2) a new solution occurs which is combined with an existing problem. A leisure time example of the first is the scientist working to develop LASIK eye surgery who was inspired to develop an effective testing method at Thanksgiving dinner. An example of the second is Scott Cook’s invention of Quicken financial software, sparked while sitting at the kitchen table discussing problems of budgeting personal finances.

In the academic literature, some progress has been made in understanding the antecedents and consequences of leisure time invention. In the knowledge management literature, the main theoretical body of research used in this paper, previous scholarship has focused mainly on analyzing the conditions under which leisure time invention arises, and how it is linked to the firm’s overall inventive efforts. Davis et al. (2013), determined that leisure time inventions are more frequently observed for conceptually-based problems (vs. science-based problems), in cases where inventor interactions with people outside the organization were important, and for smaller research and development projects.
Research on user innovation (e.g. Franke, von Hippel, & Schreier, 2006; Hippel, 1988) found that leisure time insights often inspire users in coming up with novel ideas; organizations can benefit from the commercialization of these ideas. The importance to firms of employing “embedded” lead users – employees who simultaneously work for the firm, and are users of the firm’s products – have also been explored (Schweisfurth & Raasch, 2015). Embedded lead users’ inventive insight often happen during product use in their leisure time and leads to innovation within the firm: they are likely to come up with more novel and more useful ideas than ordinary employees, because their can tap into novel need knowledge outside the organization (Schweisfurth, 2017).

Other researchers have explored the role of leisure time activities for the success of inventions made by independent inventors (Dahlin, Taylor, & Fichman, 2004; Lettl, Rost, & von Wartburg, 2009). This stream of research shows that independent inventors, as opposed to their corporate counterparts, are more likely to produce both very high and very low quality inventions (Dahlin et al., 2004). For independent inventors, highly specialized prior knowledge will lead to high quality inventions compared to corporate inventors and highly diverse prior knowledge will lead to low quality inventions compared to corporate inventors (Lettl et al., 2009).

Creativity researchers in organizational psychology have analyzed the same phenomenon but with a somewhat different focus. In particular, their work has shed light on the conditions under which work-time creativity arises (e.g. Amabile, 1996; Scott & Bruce, 1994), and the implications of the creative process for the value of the resulting invention (e.g. Woodman, Sawyer, & Griffin, 1993). Amabile’s componential framework, for example (e.g. Amabile, 1996; Amabile, 1983, 1988) shows how individual characteristics (domain-relevant skills, creativity-relevant skills, and task motivation), play out within the resource context of the work environment to increase (or decrease) creativity. Nevertheless, these frameworks do not consider the possible importance of employee creative insights while away from work. Some scholars have examined the potential contribution of particular leisure time activities for employee creativity. Madjar et al. (2002), for example, have analyzed how work and non-work support can affect employees’ creative performance in the knitting industry. Support from externals (friends and family) only affects creativity at work for individuals with low creative personality.
4 A knowledge combination perspective on leisure time invention

In the following, we restrict our analysis to the two initial stages of the innovation process (what we term “idea creation” and “idea conversion”) (cf. Hansen & Birkinshaw, 2007), where the differences between leisure time and work time invention are clearest. The further along the invention proceeds in the organization towards commercial development, the more difficult it becomes to differentiate clearly between their respective effects. This is because idea implementation, more than invention, is a socio-political process (Baer, 2012; Van de Ven, 1986): many other factors beyond the invention as such are involved in the realization of an invention’s ultimate commercial value (such as consumer preferences, the degree to which the firm is coming first or later on the market, production technology available, etc.). We argue that leisure time will affect both novelty and the ease with which ideas are converted into concepts, because leisure time invention is associated with different knowledge recombination processes than work time invention. As regards novelty, we consider the following factors:

- **The degree to which the inventive process involves distant knowledge**: this refers to whether the organization engages in problem-solving occurs outside the area of what is already known (e.g. March, 1991)

- **The degree to which the inventive process involves idiosyncratic knowledge**: this refers to whether the knowledge involved in the innovative process is specific to the inventor at hand (e.g. Galunic & Rodan, 1998).

- **The role of serendipity**: which means that inventions come unexpectedly and have not been searched for (e.g. Dew, 2009).

We additionally offer three propositions that might explain differences between leisure time and work time invention with respect to the conversion of the ideas into product concepts:

- **The degree of asymmetric information**: where one party has greater information about a particular economic transaction than another (e.g. Stigler 1961).

- **The degree to which management is able to evaluate the usefulness and importance of the invention** due to problems in areas like core competence and path dependency (e.g. Teece et al. 1997).
• **Transfer cost:** This refers to the costs of bringing knowledge developed outside the organization into the organization (e.g. von Hippel, 1994).

Figure 1 summarizes our model.

----- Figure 1 about here -----

We further restrict our analysis to the “ideal” (pure) cases of leisure time and work time invention, excluding “hybrid” forms like bootlegging innovation (Criscuolo, Salter, & Ter Wal, 2013), skunk works within organizations (Single & Spurgeon, 1996), or the 15% programs used by firms like 3M to encourage employees to think “out of the box” while at work (Gundling, 2000). We return to some of the implications of making these exclusions later in the paper.

5 **Propositions regarding the novelty of leisure time invention**

5.1 **Knowledge distance**

In the literature, a distinction is made between local and distant search. Organizations engage in local search by drawing on knowledge closely related to their existing knowledge base, and exploiting solutions that involve adapting to the current environment. It is easier to continue to do what they are already doing than to try something new (Cyert & March, 1963; Nelson & Winter, 1982); further, there is a greater likelihood of developing a successful innovation in the area in which the firm has prior experience, as confirmed in empirical studies (e.g. Martin and Mitchell 1998, Stuart and Podolny 1996). However, organizations that engage in local search tend to resist change, and are less likely to generate highly novel innovations.

Distant search, by contrast, involves crossing organizational and technological boundaries and cooperating with external sources in an effort to decrease the biases that may be associated with local search (Rosenkopf & Nerkar, 2001). This compels firms to work with new knowledge combinations, and new recombination principles, possibly involving new organizational configurations (Katila & Ahuja, 2002); it can also help the firm to understand the structure of the knowledge landscape in new ways (Ahuja & Katila, 2004). The process is irregular, the outcome unpredictable (and may even end in failure). Rosenkopf and Nerkar (2001), for example, in a study of the optical disk industry, found that exploratory search that spans both organizational and technological boundaries has the greatest impact on subsequent technological development.
beyond the optical disk industry. Katila and Chen (2008) found that distant search can lead to breakthrough radical innovations. Again, there is a downside: if the firm spends too much time engaging in search, especially uncoordinated search, and does not try to exploit at least some of this knowledge, the benefits may never outweigh the costs (March, 1991).

Applying this logic to our context, we believe that leisure time invention is more likely than work time knowledge to involve distant knowledge, for two reasons. First, since the inventor has the insight while physically away from work, she is less likely to be influenced by existing organizational routines (Cyert & March, 1963; Nelson & Winter, 1982). Such routines are important in providing organizational continuity, generating similar responses to frequently occurring activities. But they may limit the organization’s willingness or ability to strike out in new directions. Second, the leisure time inventor is more likely to engage with a variety of different people outside the organization. Scholarship in organizational creativity explores how interpersonal networks (e.g. Madjar, 2005; Owen-Smith & Powell, 2004) and strong and weak ties (e.g. Granovetter, 1973), can affect workplace creativity. Davis et al. (2013), extending this logic to understanding the antecedents of leisure time vs. work time invention, found that leisure time invention inventions were more frequently observed in cases where interactions with people outside the organization were important for making the invention.

The importance of knowledge distance for leisure time invention may be exemplified by the story of Post-it Notes (see Table 1). Fry, the new 3M product manager, had attended a seminar by senior chemist Spencer Silver, who described his discovery of a reusable, high-quality adhesive strong enough to stick to paper, but weak enough to be pulled away again without tearing. Silver was frustrated: “My discovery was a solution waiting for a problem to solve” (quoted in 3M 2002: 38). Fry’s flash of genius occurred both while he was away from work (but aware of Silver’s dilemma), and while he was interacting with other people external to the corporation.

Based on the above arguments, we posit that:

**PROPOSITION 1: Leisure time invention (compared with work time invention) is more likely to be novel because it involves more distant knowledge.**

5.2 Knowledge idiosyncracy
Specificity of knowledge refers to the extent to which knowledge is contextualized (Galunic & Rodan, 1998). Need knowledge is specific when it is tailored to a specific context of use (De Luca & Atuahene-Gima, 2007). Solution knowledge is specific when the underlying technology cannot be applied in many contexts, that is, specificity represents the opposite of what others have labelled fungibility of a resource (Danneels, 2007; Penrose, 1959). Highly specific knowledge is likely to bring novelty to organizations, because it is hard to identify. Galunic and Rodan (1998, p. 1197) note that specific “knowledge may be heavily customized to one particular use, increasing the context specificity and lowering its chances of flowing elsewhere”. That means that highly specific knowledge is less likely to be known to firms.

Extending this logic to our context, we believe that leisure time invention is more likely to be based on highly specific knowledge and thus more likely to be novel. First, leisure time inventions are often triggered when inventors “become aware of their own specific, unfulfilled needs and may be inspired to identify and solve different kinds of problems than would occur to them at work” (Davis et al., 2013, p. 1440-1442) – and thus very much rooted in the specific context from which inventors derive their inspiration.

Second, leisure time invention can be based on observations of other individuals during product use or technology application, leading to specific knowledge about technologies in use (Homburg, Wieseke, & Bornemann, 2009). Work time invention is less likely to be based on the recombination of knowledge of such high specificity. While firms do develop idiosyncratic and specific routines and capabilities that they harness to identify new knowledge, the new knowledge they absorb for innovation is closely tied to existing prior knowledge (Cohen & Levinthal, 1990) and is unlikely to include unknown idiosyncratic knowledge.

Starbucks is a good example² of the role of context-bound specific knowledge in leisure time invention. During a visit to a fair in Milan, Howard Schultz realized that espresso bars are ubiquitous in Italy and are idiosyncratic to the Italian culture. “In each shop I visited I began to see the same people and interactions, and it dawned on me that what these coffee bars had created, aside from the romance and theater of coffee, was a morning ritual and a sense of community”. (Schultz, 2017) Back in the US, he tried to convince his employers to introduce

espresso as a service. But the novelty rooted in the cultural idiosyncrasies was too much for the owners, who claimed that espresso bars were “not what Americans wanted.” (Schultz, 2017)

Summarizing the logic from above, we suggest that

**PROPOSITION 2: Leisure time invention (compared with work time invention) is more likely to be novel because it involves more idiosyncratic knowledge.**

5.3 Serendipity

Serendipity describes the accidental discovery of something that is valuable ex post (Pina e Cunha, Clegg, & Mendonça, 2010). A variety of scientific breakthrough involve serendipitous elements, e.g. penicillin, x-rays, nylon, Viagra, Teflon, dynamite, and PVC (Austin, Devin, & Sullivan, 2012). Serendipitous discovery is likely to be very novel, since it produces something unexpected and beneficial that has not been there before (Yaqub, 2018).

Serendipity has been conceptualized as a search process that leads to unintended discoveries (Dew, 2009). This search process is guided by the prior knowledge of the searching entity, which affects the preparedness for new knowledge. As Louis Pasteur expressed it, chance favors only the prepared mind. An example of serendipitous invention is LASIK; Scientists at IBM’s Watson Research Center knew they needed a texture similar to the human eyeball on which to practice. Rangaswamy Srinivasan’s Eureka moment at Thanksgiving solved the problem. Another example is Post-it Notes, where Fry’s hymnal marker unexpectedly fluttered to the floor.

We suggest that the search for invention during leisure time is more likely than work time search to result in serendipitous discovery, because it is more likely to be associated with factors facilitating serendipity. First, leisure time invention is more likely to be related to bisociative thinking (Koestler, 1969), that means the connection of otherwise disparate knowledge domains. Individuals who look for solution or problems inside the work context are restricted to one context. If individuals expand the search outside the boundaries of the firms, they are much more likely to connect existing knowledge to new domains they have not been set out to before. This knowledge that individuals are confronted with during their leisure time is likely to involve many different domains of knowledge that may be close or far to the inventor. This diversity increases the likelihood that individuals can connect new domains and engage in bisociative creative thinking. Bisociation is an important element of serendipity (Pina e Cunha et al., 2010).
Second, leisure time invention is more likely to involve individuals into the ideation process that are normally not involved in work time invention. During leisure time inventors establish new connections that potentially help to access new knowledge domains. Social capital and access to social networks is likely to facilitate serendipitous discoveries (Pina e Cunha et al., 2010).

Third, as leisure time invention does not happen within the organization, it is more likely to represent a context in which serendipity can flourish. Within the organization, inventors are likely to be affected by evaluation apprehension that is they inhibit unconventional ideas because of fear of negative reactions from the organization (Girotra, Terwiesch, & Ulrich, 2010).

Synthesizing the above points, we propose:

**PROPOSITION 3: Leisure time invention (compared with work time invention) is more likely to be novel because it is more likely to be discovered by serendipity.**

### 6 Propositions regarding the conversion of the idea into a viable product concept

A classic challenge faced by managers is that they can only develop a certain number of the potential important inventive insights presented to them. They need to make priorities in a cost-efficient manner, sorting through different types of ideas and choosing only the most promising ones. Leisure time invention, like work time invention, may or may not lead to a useful or important invention. In this section, we develop the argument that leisure time invention will be relatively more difficult to convert into a product concept within the organization, for the following three reasons.

#### 6.1 Asymmetric information

First, there will arguably be a greater degree of asymmetric information (e.g. Stigler 1961, Akerlof 1970) between the leisure time inventor and the manager of his company than for the work time inventor, since managers cannot observe what their employees are doing while away from work. Thus the leisure time inventor has more or better private information about the invention than the manager. Information asymmetry can lead to market failure, and thereby an inefficient allocation of goods and services. Applied to the context of this paper, this might mean that potentially valuable leisure time inventions do not get commercially developed, at least by
the company that employed the inventor. Managerial challenges grounded in asymmetric information are aptly demonstrated by the examples of Post-it Notes, the Apple computer, and Starbucks Coffee.

A different dynamic is illustrated by LASIK eye surgery (where Srinivasen’s private information was easily communicated to the other members of the project team), and the invention of controlled flight (Bereiter 2009). In this latter case, there was no asymmetric information at all, since the Wright brothers were management. They themselves performed the necessary knowledge combination, drawing on knowledge sources from the engineering literature, their bicycle experiences and equipment, and observations of vultures in the wild. Back in the bicycle shop, Orville and Wilbur conducted experiments by mounting small test wings on the handlebars of a bicycle, ridden at a particular speed through a primitive wind tunnel of their own design. After testing more than 200 model wings, they succeeded in designing successful wing warp. Had they instead been employees of a bicycle shop, where management could observe their attempts to convert their leisure time insights into airplane technology, facilitated by their subsequent (strange) experiments using bicycles, this story might well have ended differently.

These arguments lead to the following proposition:

**PROPOSITION 4: Leisure time invention (compared with work time invention) is more difficult to organizationally convert into a viable product concept due to a higher degree of information asymmetry between employee and manager.**

6.2 Management uncertainty in evaluating the importance and organizational impact of the invention

Second, management will arguably experience greater uncertainty in judging the potential usefulness, importance and organizational impact of the leisure time invention, compared with the work time invention. This is because, first, the invention is less likely to be in the area of the firm’s existing core competencies. At 3M, for example, management concluded that Silver’s weak adhesive did not “fit” with 3M’s broader expertise in strong adhesives. Silver’s invention might well have languished but for Fry’s insight in the choir box, and passion to build a working prototype in his basement. However, without the benefit of hindsight, it is hard to fault 3M management for its initial skepticism.
Core competencies define the firm’s fundamental business (Teece et al. 1997). According to the resource-based perspective (e.g. Barney 1986, 1991), sustainable competitive advantage is enabled by accruing rents from firm-specific assets (resources that that are valuable, rare, imperfectly imitable, and non-substitutable). A fundamental assumption is that firms are heterogeneous in their resources and capability. These resources are also “sticky” to some degree, and costly to change (Dierickx and Cool 1989). Firms cannot easily alter their resource position, whatever the potential benefits that might come from such a change.

Second, research on path dependency shows that “history matters”: the set of decisions a firm faces is limited by the decisions it has made in the past (or the events it has experienced), even though these past circumstances may not be relevant today. Investments in past projects typically shape the basis for investments in further projects within the firm (Nelson and Winter 1982, Dosi 1988). In the case of Starbucks, for example, management was fine with selling coffee; why should they go into the restaurant business? To do so would require them to move away from their familiar path to embrace a costly and possibly quite fruitless endeavor.

Related work discusses the role of the firm’s willingness to “cannibalize” its investments: defined as the degree to which it is prepared to reduce the actual or potential value of its current specialized investments (which will lose value if they are not applied to a specific technology) and make new ones with a greater potential to serve future markets. Chandy and Tellis (1998) found that willingness to cannibalize was a strong driver of radical innovation.

Finally, leisure time inventive activity might be resisted by internal personnel due to the “not invented here” syndrome, reflecting a prejudice against externally inspired inventions (Antons & Piller, 2015; Katz & Allen, 1982). Ideas created by one employee (or group of employees) might have unintended, negative effects on other employees (Janssen, Van de Vliert, & West, 2004; Shalley, Zhou, & Oldham, 2004). We believe that leisure time invention would be more likely to encounter the not-invented here syndrome than work time invention, since it does not arise directly in the context of workplace activities.

Leisure time invention might provide a way by which a firm can break away from the “safety” of its current investments. But for Schultz’s bosses at Starbucks, it wasn’t at all clear that customers (or even their own employees) would embrace the idea of Italian-style coffee bars. Wilbur and Orville Wright, by contrast, didn’t view their work on airplanes as cannibalizing their bicycle
business. They even used their experiences taking out patents on bicycle technology to aid them in patenting their invention of the airplane. Entrepreneur Scott Cook was equally unperturbed by concerns about his previous firms’ customers and employees; he simply started up a new firm.

In summary, we advance the following proposition:

**PROPOSITION 5: Leisure time invention (compared with work time invention) is more difficult to organizationally convert into a viable product concept because it is more difficult for management to judge its usefulness and importance**

### 6.3 Transfer cost

We argue that leisure time invention will be more difficult than work time invention to convert into a viable product concept because the knowledge is more costly to transfer. Knowledge transfer can be conceptualized as information processing, in which information (about the leisure time invention) is transferred from a sender (the leisure time inventor) to a receiver (the organization) (Shannon & Weaver, 1949). Some information is more costly to transfer than other information because it is sticky – this refers to “the incremental expenditure required to transfer that unit of information to a specified locus in a form usable by a given information seeker” (von Hippel, 1994, p. 430). The costs of knowledge transfer are based on the nature of the knowledge being transferred, and the receptivity of the organization.

As regards the first, we have argued above that knowledge included in leisure time inventions is more distant and more idiosyncratic than knowledge included in work time innovations. This knowledge is not directly transferrable to other context and may lose value if it is directly applied in other contexts. Thus it needs to be reframed and altered to be used within the organization, which results in transfer costs. For example, at the time of Fry’s leisure time insight, 3M did not possess the coating equipment that could function precisely enough on an imprecise backing like paper (see http://www.3m.com and Reid and De Brentani 2004).

As regards organizational receptivity, leisure time invention incorporates knowledge that differs from the knowledge embedded in the organizational routines because it stems from domains unknown to the organization. In order to integrate such knowledge from the leisure domain, the firm can either establish rules, procedures, or boundary objects that help to foster this interpretation process (Carlile, 2004), or build routines that help to transform and utilize
knowledge from the leisure domain. Both would foster the organization’s absorptive capacity towards the leisure domain (Cohen & Levinthal, 1990), that is, the firm’s ability to recognize, interpret, and utilize leisure knowledge. Since building absorptive capacity for a field that is new to the firm (such as knowledge from the leisure domain) is more costly than maintaining absorptive capacity in a field native to the firm (such as knowledge from the work domain), knowledge transfer from the leisure domain is likely to require higher investments. Returning to the case of the Wright brothers, had they instead, as employees, been forced to justify the need for their many (costly) investments in time and resources in bicycles to management, they might well have been told to stop.

A further example of how leisure time invention is likely to be costly to transfer into the organization is the invention of Nivea Stainless Deodorants (Lakhani, Füller, Bilgram, & Friar, 2014). Stephan Biel, a Nivea employer and user of Nivea’s deodorant, had a problem. Because the deodorant stained his white shirts, he too often had to buy new shirts. But it was hard for him to solve the problem by a product concept. First, the knowledge about this need was distant to Nivea and could not be directly transferred into a chemical formula. Second, the knowledge about this need seemed too narrowly idiosyncratic to the organization, as Biel’s supervisors apparently did not suffer from stains. Biel had to invest much effort to finally secure the resources needed to champion the development of his leisure time insight within Nivea. Overcoming all of these issues involves high transfer costs.

All in all, we submit:

**PROPOSITION 6: Leisure time invention (compared with work time invention) is more difficult to organizationally convert into a viable product concept because it is more costly to transfer the knowledge**

7 Discussion

We have sought, in this paper, to contribute to the literature by identifying the circumstances under which leisure time invention, as opposed to work time invention, affects innovation in firms. This section elaborates several further interpretations and extensions to the arguments advanced in our six propositions.
First, with regard to the propositions on novelty, the logic connecting knowledge distance with the incidence of leisure time invention (Proposition 1) refers to distance between the location of the inventive insight and the employee’s firm, not the distance between the insight and the context (away from work) in which the employee made it. For example, 3M’s Art Fry’s insight, to coat a scrap of paper coated with a weak adhesive to be used as a bookmark, was not very different from the current solution (an uncoated paper bookmark). But it was quite different from the strong adhesives produced by 3M.

Another example is Wozniak’s invention of the personal computer (Audia and Rider 2005). His first creative flash occurred on a date. Looking at the arcade game, PONG, with his girlfriend, he realized he could develop a computer version of the game. His second insight came when he observed how “Captain Crunch” wrote a computer program connected through a telex machine to an ARPANET, so that when he typed on a keyboard, the letters appeared on a screen. Wozniak combined these insights with his job-related knowledge of computer technology to design the first Apple computer, consisting of a motherboard, a keyboard, and a power supply.

He, like Fry, got his insight while away from work (but in possession of his workplace knowledge), and while interacting with outside people. Wozniak’s resulting invention (a primitive computer), in essence, was not too different from his observation of Captain Crunch and the telex machine – but was quite unlike HP’s work on electronic calculators.

The importance of idiosyncratic knowledge (Proposition 2) has been emphasized in related work in the literature on user innovation, where individuals come up with specific solutions for their idiosyncratic needs in their leisure time (von Hippel, 2005). Often, such user innovators successfully implement their leisure time inventions in the organization they work for (Schweisfurth & Raasch, 2015). The leisure time invention of Quicken, similarly, was grounded in idiosyncratic knowledge about one user’s irritation with existing budgetary tools.

As regards serendipity (Proposition 3), our paper has implications for the role of organizational concepts like autonomy. For serendipitous discovery to happen, inventors have to have autonomy in innovation processes. As serendipity has an unexpected element, it is less likely to be mainstream and may run counter conventional wisdom (Murayama, Nirei, & Shimizu, 2015). During leisure time, individuals are less likely to suppress such new unexpected ideas. They can take the time and autonomy to deliberate their invention.
Our findings additionally have implications for research on how organizations convert ideas into viable product concepts. With regard to information asymmetry (Proposition 4), one might ask: Under what circumstances do – and should – employees reveal their leisure time insights? If the employee believes that her private knowledge might worth something to her employer, she might choose to keep the knowledge to herself, with a view perhaps to starting her own firm (as exemplified by Scott Cook), or even to selling the information to a competitor. In both cases, she may well have the incentive to leave her current employer. Alternatively, she can reveal the knowledge to her employer in the hopes of a reward if it is integrated in an internal project – or perhaps forms the basis for a management-sanctioned corporate “spin-off.” (Hellmann, 2007)

Seen from this perspective, it is in management’s interests that employees reveal their leisure time ideas. In many countries, such as Germany, the law mandates that the employer owns the rights to employee inventions, even where the inspiration has occurred in the inventor’s leisure time. Other firms have employment contracts with clauses, variously termed “trailer clauses,” “invention assignment agreements,” or “holdover clauses” which essentially claim as firm property any employee invention relating to that firm’s business, extending in some instances to cover areas unrelated to the firm’s core competences. For example, employers can offer workers ex ante incomplete contracts, typically with trailer clauses (giving ownership of an invention to the employer if the inventor leaves the firm for a specified period, after which it can revert to the employee), shop rights clauses (conferring ownership of patents to the discoverer while conveying a nonexclusive, non-assignable and royalty-free license to the employee to use the invention), and other forms of incentive contracts contingent on management objectives (Aghion & Tirole, 1994).

One can only speculate as to what Hewlett-Packard management might have gained had they invoked such an arrangement when Wozniak approached them about his idea. As Wozniak recounts the story:

- “The very first thought in my mind was, ‘I think I signed a document that everything I design belongs to Hewlett-Packard.’ Even just on my own time, I thought that they deserved it first. And I wanted Hewlett-Packard to build this… I went to management, and I had three levels of bosses above me in a room and a couple of other engineers, and I presented the ideas and told them what we could do at what price and how it would work. They were intrigued by it, but they couldn’t justify it as a Hewlett-Packard product…So I got a written response back from them that no divisions were interested.” (quoted in
Livingston, 2007; the story is reproduced in http://foundersatwork.com/steve-wozniak.html).

Seen from the leisure time inventor’s point of view, on the other hand, sharing knowledge with her employer also means revealing that she may have been “wasting” valuable company time – without this admission necessarily yielding any economic benefit to her. Leaving the firm without revealing her insight might therefore be appealing, particularly if there are no contractual trailer clauses, if the clauses are not enforceable, if the information cannot be proven to be deleterious to her original employer, and if her firm cannot claim the intellectual property rights. Leisure time invention thereby provides an interesting variation of the problems of employee retention, given that such employees often are assets to their employers. While management might not immediately realize the value of the leisure time invention, they might still allow the employee to pursue this line of research, to the degree that this facilitates employee retention.

In the case of Post-it Notes, for example, Bob Molenda, Fry's supervisor and the special projects lab coordinator, helped Fry to find the time and money to develop his pet project through the pilot test period. Had Molenda not helped Fry, would Fry have stayed with the company? It is impossible, of course, to answer this question. Interestingly, even though neither Fry nor Silver ultimately received any special financial compensation for developing Post-it Notes, both continued on at the company to invent new products.

With regard to our proposition on management uncertainty (Proposition 5), an important reason why management may be unreceptive to the inventor’s (even promising) new idea is that they are reluctant to break with their firm’s core competencies. One might perhaps claim that HP was short-sighted and missed a great opportunity when it let Wozniak go. But should a rational HP management have abandoned their existing focus on calculators, which embodied their core competencies, and thrown their resources into unknown territory? The answer is not at all clear. By contrast, the test method suggested by Srinivasan did not require the IBM research center to abandon its core competencies.

A key explanation might be found in theoretical work by Tushman and Andersen (1986): that innovations may be either competence-enhancing (building on something the firm already knows, enabling it to strengthen its position) or competence destroying (building on something different, requiring new learning, skills and knowledge, and requiring the development of new
competencies). We believe that this distinction might be important in understanding management receptiveness to leisure time invention.

Leisure time inventions that are competence-enhancing (as in the IBM case) will clearly be easier to convert into viable product concepts than leisure time inventions are competence-destroying (as in the HP case). IBM was actually able to build on and further develop its core competences following Srinivasan’s leisure time insight. One of his colleagues, James Wynne, continued to work at the IBM center, focusing decades later on devising new medical applications for the ArF excimer laser, a further development of the original LASIK technology (Wynne, 2012). 3M was eventually willing to move into weak adhesives, even though it required new investments in machinery – but it ultimately doesn’t seem to have rendered the firm’s main existing core competencies (in adhesive-making generally) obsolete. Schultz’s Starbucks, by contrast, had to develop a completely new business model.

Finally, transfer cost (Proposition 6) will differ according to the nature of the invention. Srinivasan’s leisure time insight was much less costly to transfer than Fry’s. Srinivasan only needed to bring the turkey carcass to the IBM lab and see if it worked for testing: the idea didn’t lose value by being applied in a different context, and it didn’t require costly new investments. Fry had to persuade management both to support an idea which had to be applied in a new context (weak adhesives), and to invest in new machinery.

Our results thereby add to the emerging literature that analyzes how the employee’s life outside the organization affects the innovativeness of her organization within (e.g. (Harrison & Wagner, 2016). We believe that leisure time invention can potentially play an important role in enhancing work time innovation – but only if it does not involve too great a change, as would be the case if it threatened the organization’s core competencies. It can also provide a sound basis for the leisure time inventor to start a new innovative firm, like Intuit.

An extension of our analysis could be to explore the various “hybrid” examples of leisure time and work time invention we have excluded from our analysis. Fry, for example, took advantage of 3M’s “15 percent time” program to pursue his project. Individuals may also engage in bootleg projects at work to investigate unproven ideas, going “underground,” out of the sight of managers (Criscuolo et al. 2013), or engage in “creative deviance,” continuing to work on bootleg projects formally ended by management (Mainemelis 2010).
Furthermore, many employees today take work home. Might this be conducive to greater creativity? It is not really “leisure time,” as defined it here. But it takes place while the employee is physically away from work. To what extent does this lead to more novel but less easily convertible inventions within the organization? This whole range of “hybrid cases” could provide a rich focus for future research. Perhaps the ideal types of leisure time and work time invention might best be seen as the extreme points along a continuum comprising a range of alternative, combined approaches.

8 Limitations and future research

As with all scholarship, this paper builds on a series of assumptions that both restrict the scope of our analysis, but suggest avenues for future work. First, leisure time invention has a broader, societal relevance. Since the leisure time inventor by definition is not engaged in paid work when she gets her inspiration – but where the inspiration may well still be relevant for her workplace – leisure time invention can be seen as a form of unpaid work (Beneria, 1999). If so, it represents a key – if largely unrecognized and untapped – source of welfare-enhancing activity.

Our results suggest that leisure time invention can be valuable – but that it can be quite difficult to link the source of the inventive insight with the value of the resulting innovation. A key problem here is that leisure time inventive activities might, in fact, take time and energy away from what these employees are supposed to be doing at work. Again, this problem is not limited to leisure time invention; as Shalley, Zhou, & Oldham (2004) point out, employees might spend too much time and effort developing new ideas that they have little energy left to complete their normal assignments. But we believe that this problem would probably be more acute for leisure time invention. Added to this, research has shown that many, probably most, leisure time insights have no value (cf. Dahlin et al., 2004). Managers have limited time and much else to do beyond listening to their employees’ leisure time insights. At the same time, if the insight is not revealed, its putative value cannot be determined.

In our discussion of need knowledge vs. solution knowledge, we do not differentiate between leisure time and work time invention along these dimensions. Future work could assess the degree to which leisure time invention is more likely to be focused on needs than solutions. By extension, research might also examine whether need knowledge in a leisure time invention is
less susceptible to management uncertainty, say, but more costly to transfer, than need knowledge in a work time invention – or vice versa.

Scholars could additionally explore how managers might better realize the potential of leisure time invention by reducing the incidence of information asymmetry (perhaps by fostering better observability between employee and manager), leveraging leisure time invention to break free of competency traps and problems of path dependency (perhaps by underlining the importance that the firm needs to continue to explore and learn, and build new competencies), and finding ways to transfer knowledge related to the leisure time insight more efficiently (perhaps by finding ways to foster greater organizational absorptive capacity in relation to these ideas).

9 Conclusion
Our research suggests that leisure time invention is a phenomenon worth studying in greater detail, since it differs from work time invention in important ways. We outline the most important reasons for this, and generate propositions that argue that leisure time invention is both more novel than work time invention, and more difficult to convert into products within the organization. If empirical research bears this out, it indicates that organizations might be advised to try to address this phenomenon in a more effective way than currently is the case.
References


Intuit; The history of quicken - from kitchen table to boardroom table; http-download.intuit.com/...quicken.../History_of_Quicken.doc.


28

Wozniak, S. 2006. How I invented the computer FORA.


Figure 1: A model of leisure time invention and its effect on idea creation and conversion
## Table 1: Six leisure time inventions

<table>
<thead>
<tr>
<th>Invention</th>
<th>Inventor</th>
<th>Description</th>
<th>Invention process</th>
<th>Knowledge combination: idea creation</th>
<th>Knowledge combination: idea conversion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-it Notes</td>
<td>Art Fry, chemical engineer at 3M</td>
<td>3M chemical engineer Art Fry had been trying to find a use for a non-sticky adhesive invented by his co-worker Spencer Silver. One night, while at church choir practice, and irritated that his hymnal book markers kept falling out, he was struck by the thought that this adhesive could be attached to pieces of paper to mark his place. But when he presented his idea to 3M management, they were skeptical that such an idea would create value for a firm specializing in strong adhesives. Fry took advantage of the company’s “15% rule” enabling companies to pursue pet projects while at work, build a prototype machine in his basement, and sold samples to employees, who loved it – finally persuading 3M management to put the kinds of heavy resources into the project to commercialize it, with huge success.</td>
<td>New need combined with an existing solution</td>
<td>Work time knowledge of weak adhesives combined with leisure time insight about how the adhesive could be attached to paper to mark his place in the hymnal.</td>
<td>3M management initially skeptical, Fry build the prototype in his own basement and “sold” management on the idea by making samples for fellow employees</td>
</tr>
<tr>
<td>The Apple computer</td>
<td>Steve Wozniak, computer engineer at HP, and Steve Jobs, video game director at Atari</td>
<td>Steve Wozniak was a young computer engineer at HP, working to develop its 65 and 75 scientific calculators. His friend, Steve Jobs was a video game developer at Atari. Wozniak, who spent many hours at the Homebrew Computer Club, observed how „Captain Crunch“ had written a computer program, without a screen (as was commonly done at the time), linked through a telex machine to an ARPA-net screen in Boston, Massachusetts. Inspired by this, Wozniak and Jobs decided to develop an interactive computer. In 1975, Wozniak presented their crude prototype to HP management, who said they were not interested in going further with the project. He left HP and the two inventors built the prototype for Apple 1 in Jobs’ parents’ garage.</td>
<td>New need combined with an existing solution</td>
<td>Work time knowledge of electronic calculators and computer games; leisure time insights about the potential of interactive computers at the Home Brew Computer Club</td>
<td>HP management wasn’t interested in developing the computer prototype; Wozniak and Jobs left their companies and founded Apple</td>
</tr>
<tr>
<td>Starbucks coffee bars</td>
<td>Howard Schultz, director of marketing, Starbucks Coffee Company</td>
<td>Howard Schultz was the director of marketing at Starbucks Coffee Company, which sold whole coffee beans, leaf teas, and spices. While on a buying trip to Milan, he noticed that coffee bars existed on virtually every street, served delicious coffee, and served as public meeting spaces. Back home, he tried to persuade the owners to offer espresso beverages as a service. Management was reluctant to get into the restaurant business. Schultz left the company to start his own coffee bars. Later, he returned to Starbucks and successfully reoriented the company from retailing to the espresso bar business.</td>
<td>New solution combined with existing need</td>
<td>Special importance of: Knowledge distance • Serendipity</td>
<td>Special importance of: Asymmetric information • Management uncertainty • Transfer cost</td>
</tr>
<tr>
<td>LASIK eye surgery (Wynne, 2012)</td>
<td>Rangaswamy Srinivasan, IBM scientist</td>
<td>In 1981, IBM scientists had been experimenting with a new method to shoot lasers at the human eye with the aim of improving the person’s eyesight. The problem was how to do this without destroying the surrounding tissue. The scientists needed to identify a suitable surface that was similar to the human eyeball on which to practice. One member of the team, Rangaswamy Srinivasan, had a flash of genius while taking a break to enjoy a Thanksgiving feast with his family: that a turkey bone with a little cartilage on it would have just the right consistency for this test. Srinivasan whipped the turkey carcass away from his family, bagged it, and brought it to the lab. There the team shot pulses of light from their new laser machine at the turkey. Happily, none of the surrounding turkey tissue was damaged. The IBM scientists went on to develop a technology that would eventually help many millions of people gain better eyesight.</td>
<td>New solution combined with existing need</td>
<td>Work time knowledge of laser technology with leisure time knowledge of turkey bones</td>
<td>Management was supportive of developing the new technology</td>
</tr>
<tr>
<td>Quicken financial management software (Intuit) (Intuit, 2006)</td>
<td>Scott Cook, marketing manager at Procter and Gamble, was sitting at the kitchen table, listening to his wife complaining about the difficulties of organizing a domestic budget. He was suddenly struck by the insight that he could use his work time expertise, in cooperation with colleague Tom Proulx, to develop computer software system to create a digital program to automate the whole bill-paying process. Inspired by Proctor and Gamble’s business model, the two men decided to create a product based entirely on what consumers wanted. After extensively talking to people about their financial habits, Cook found there was a huge need for a faster, easier way for them to manage their personal finances. They founded a company called Intuit to communicate this message. The result, Quicken, soon achieved wide use.</td>
<td>New need combined with existing solution</td>
<td>Work time knowledge of computer software combined with leisure time insight about the need for an easy system to manage household finances</td>
<td>Special importance of: • Idiosyncratic knowledge</td>
<td></td>
</tr>
<tr>
<td>Controlled flight (wing warp) (Bereiter 2009).</td>
<td>Orville and Wilbur Wright, owners of and mechanics at a bicycle/ printing shop</td>
<td>In their leisure time, the brothers spent time designing flying machines. They were avid readers of the flight engineering literature, where they learned about the advances made by pioneers like Otto Lilienthal and Octave Chanute to improve the structural soundness of the wing. But no-one had solved the problem that arose in the early experiments: that when a flying machine turned too quickly in the air, it crashed. One day, while picnicking, the brothers observed how gliding buzzards made controlled turns, twisting one wing upwards and the other downwards. Wilbur Wright picked up a cardboard box (that had earlier contained a bicycle inner tube), twisted it, and found that it replicated buzzard “wing warp.” Back at the bicycle shop, the two men build on this insight, eventually constructing a flying machine that could safely turn while airborne.</td>
<td>New solution combined with existing need</td>
<td>Work time knowledge of bicycle technology combined with leisure time reading of flight engineering publications and observations of vultures in the wild</td>
<td>As owners of the bicycle shop, the brothers could use their knowledge of bicycle technology and flight engineering to design the first successful flying machine</td>
</tr>
</tbody>
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32