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Selection of appropriate lead users for new product development in co-creation: further development of the lead user method in the context of medical device innovations

Doctoral dissertation

Supervisor: Dr. habil Tibor Dőry

associate professor

Győr, 2022

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Author’s Declaration

No portion of the work referred to in this dissertation has been submitted in support of an application for another degree or qualification of this or other university or other institution of learning.

Furthermore, this dissertation contains no material previously written and /or published by another person, except where an appropriate acknowledgement is made in the form of bibliographical references.

Abstract

Abstract of the dissertation submitted by: Béla Venesz

For the degree of Doctor of Philosophy titled "Selection of appropriate lead users for new product development in co-creation: further development of the lead user method in the context of medical device innovations".

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Involving appropriate lead users in the NPD (new product development) process is particularly challenging, as the contribution of individuals varies strongly because the personal characteristics of users differ significantly. Although the lead user method sets two criteria to identify lead users, it does not consider the personal characteristics of lead users that are required to achieve success in the lead user co-created NPD.

The dissertation consists of six Chapters. The first part aims to ensure conceptual clarity of the Dissertation through the definitions of fundamental terms, including the process from closed to open innovation, user innovators, the lead user concept, and the most common lead user identification processes. The second Chapter focuses on the establishment of the problem statement and proposing research questions for further investigations. Chapter three presents the personal motivation of the author to conduct his research, demonstrates the research design of the included papers, and also provides the roadmap of the Dissertation. Chapter four includes the systematic literature review that was published in a Journal. Chapter five contains the second paper (case study research) which at the time of the dissertation is submitted and reviewed by the selected Journal. The last Chapter summarizes the theoretical and practical contribution of the dissertation as well as links the new knowledge to the existing knowledge, more specifically to the original lead user method. The section ends with a summary of the key results and theses.

The key result of the dissertation is the meaningful contribution to the theory by extending the lead user method with an additional step called the "lead user cognition partial method". The extension refers to the cognition process of the decision maker during the selection process of appropriate lead users for the co-created NPD process. The research provides also novel insights including the six personal characteristics of lead users that are required to achieve technical and market success in the co-created NPD process in the dedicated context of medical device innovations. The conclusion presents further novel insight as lead users

need to be involved at each stage of NPD to achieve success in the co-created new product development. It is an important outcome of the research that the process of lead user selection is regardless of product complexity.

The dissertation reveals also managerial implications by recommending signals for practices that facilitate the selection process of proper lead users in the fuzzy front end of the co-creation and therefore reducing the uncertainty, cost, and time of the NPD.

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My sincere thanks also to the guru of my research topic Professor Eric von Hippel during our conversation at the OUI 2021 conference and the following up online discussion on the extension of the lead user method initially published by him. His appreciation and comments motivated us to shed light on important - though neglected – aspects and advance our research design.

I would like to thank Professor Harry Boer for his effort in reviewing both of my articles and for providing very detailed and constructive feedback that was needed to be able to submit our article to prestigious journals.

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Key to abbreviations

SLR - systematic literature review

NPD - new product development

LuCog - lead user cognition method

1. Introduction

As innovation is a rather complex phenomenon that has different meanings for researchers and practitioners, we start this section with some definitions. To ensure the conceptual clarity of our study and also the provide the right understanding of the research and its results and conclusion, we define the following fundamental terms as innovation, open innovation, new product development, user innovators, co-creation, the lead user concept, and the lead user method.

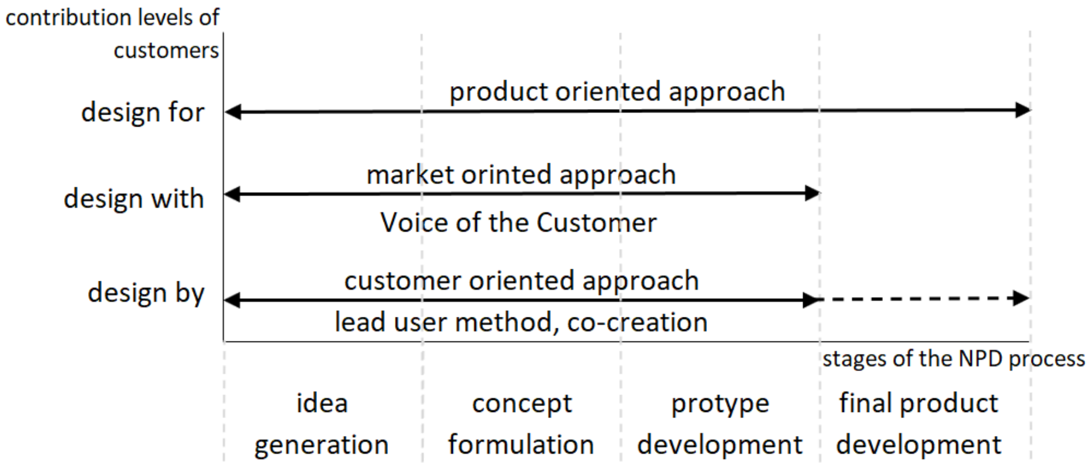
1.1. From closed to open innovation

Innovation for customers. In the early days, business managers and policymakers assumed based on Schumpeter's (1934) theory that the “producer model” is the dominant mode of innovation (von Hippel, 2005). The evolving “mass production society” (Sheth, Sisodia and Sharma, 2000) and the seller-market phenomenon were triggered by the *product-centred approach* where products were designed *for customers*. In the traditional sense of innovation, customers remain passive stakeholders of the innovation process by responding with rejection or acceptance of the innovation. “The producer who as a rule initiates economic change, and consumers are educated by him if necessary” (Schumpeter, 1934, p. 65). At this time innovation-active organisations solely rely on their own internal resources and need-, and solution knowledge to develop their new products.

Innovation with customers. At the end of the 1950s, companies started to change their attention from a product-centred mindset to a *market-orientated approach*. Drucker (1954) forced this change as he argued that the satisfied customer shall be the focus of the business purpose. Kotler (1967) fostered further the market-oriented perspective, which had soon been adopted. Producer firms started to pay more attention to customers’ needs, requirements, feedback and reaction. The innovation and product design took place together *with customers* by utilizing e.g. the Voice of the Customer method.

*Innovation by custome*rs. Towards the end of the 20th century, the value chain changed from the perspective of the provider to the customer (Piller, Ihl and Vossen, 2012). The competitiveness of a company was determined by the ability to deliver unique value to serving customers by considering customers as individuals (Piller and Walcher, 2006). According to the *customer-centric approach*, firms organised their resources and abilities to respond to customer demand instead of creating demand and trying to influence customers what, when and how to buy. This process led to the phenomenon of open innovation, which means that firms open their corporate boundaries to involve knowledge, experience, ideas of multiple actors such as customers and users and set up close collaboration with them through their active participation in the new product development (NPD) process (*design by customers*). Although the external sources of innovation can vary (Bessant and Tidd, 2015), the focus of a customer-centric enterprise turned to customers and users as the major source of innovation (Urban and von Hippel, 1988). Figure 1.1. shows the different levels of customer contribution in the NPD process of firms.

Figure 1.1. Customers' level of contribution to the new product development



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The **definition of innovation** has changed through the decades therefore it is crucial to define the term and consistently employ it in our studies. We use the definition of the recently published Oslo Manual which states that "an innovation is a new or improved product or process (or a combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)" (OECD and Eurostat, 2018). In our interpretation, the new product shall be new-to-the-world regardless of its complexity and its incremental or radical status. A further criterion is that the innovation must enable firms to realize profit by selling the new product on the market.

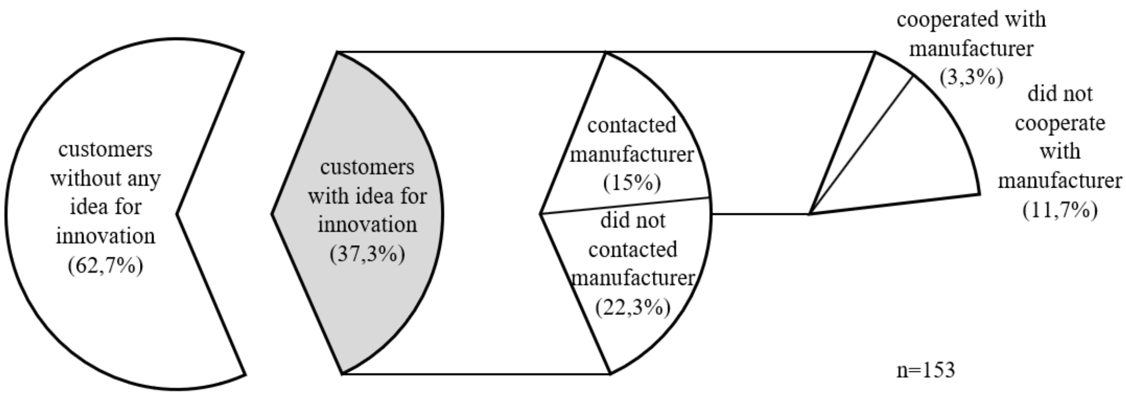
We define the term **new product development** as a process that describes the designated steps of firms that transform the idea into marketable products. The process consists of well-established stages including idea generation and concept formulation, product development, product testing and market diffusion phases. An NPD process is considered successful when the new product development process reaches the status of innovation reported by the chief executive officer of the company.

The dissertation is organised as follows: the recent chapter reviews and defines the conceptual background of the dissertation including the evaluation of innovation, user innovators, co-creation, the lead user concept and method. Chapter 2. formulates the problem statements and indicates the research questions, while Chapter 3. describes our findings, conclusions and the contribution of our study. Chapter 4. presents our first article and the final section contains our second article.

1.2. User innovators

According to Baldwin and von Hippel (2009), a large number of users (10 per cent to 40 per cent) modify or develop different types of industrial and consumer products by themselves including low-tech fields like Hilti AG (Herstatt and von Hippel, 1992), or medical equipment (Lüthje, 2003; Lettl, 2007a), mountain bikes (Lüthje, Herstatt and Von Hippel, 2005), and sport-related products (Lüthje, 2004), OPAC library information system (Morrison, Roberts and von Hippel, 2000) computer-aided design (CAD) (Urban and von Hippel, 1988). According to Lüthje (2004), 37,7% of the customers have innovative ideas and 15% contact firms to share their ideas or contribute with manufacturers (3,3%) as Figure 1.2. shows.

Figure 1.2. Consumer-manufacturer interaction



Source: Lüthje (2004)

In contrast, while users expect the benefit directly from the innovation, producer firms await profit from selling the innovation-related product (Urban and von Hippel, 1988). Innovative users can choose from different options to fulfil their needs: 1. commercializing the innovation by becoming an entrepreneur and manufacturer (Baldwin *et al.*, 2006; Haefliger *et al.*, 2010; Shah and Tripsas, 2011); 2. transferring their idea to a manufacturer (Lüthje, 2004a; Chen *et al.*, 2019)(Lüthje, 2004a); 3. setting up collaboration with a producer firm and realizing the innovation together in a form of co-creation.

From the perspective of the company, there are three approaches to interacting with users in the innovation process: 1. the market-oriented approach, when companies fulfil customers' needs by listening to the customer domain; 2. the customer-oriented approach, e.g., the Voice of the Customer method (Green, Carroll and Goldberg, 1981; Griffin and Hauser, 1993), when customers are asked via a market survey for the input to the company innovation process; 3. the third approach refers to the term of co-creation where appropriate users are actively involved into the NPD process.

1.3. Co-creation with users

Managing market needs and technical solutions-related uncertainties can be regarded as a central activity of a successful innovation management process (Piller, Ihl and Vossen, 2012). According to studies new product development is a high-risk endeavour as approximately 46% of the NPD are unsuccessful, 35% of the product launched fail commercially after the product development and testing process, and only 13% of the firms report that the new product achieved their annual profit expectations (Cooper and Kleinschmidt, 1987, 2000; Brem, Bilgram and Gutstein, 2018; Cooper, 2019). Uncertainty becomes more evident in the case of high product complexity. In the dissertation, we refer to Senders (2006) to define product complexity: a product is judged highly complex when its operation required programmatic logic, otherwise, it is considered as low complexity.

In order to reduce uncertainty, firms need to access different kinds of information like market needs (**need information**) and information on technical possibilities (**solution information**). Both information might be located physically outside of the firms' boundaries, external to the NPD. Product users are in the best position to collect use-experience and provide their need- and solution knowledge to the producer firm. Successfully innovating firms involve users (Bradonjic, Franke and Lüthje, 2019; Franke and Lüthje, 2020), customers (de Jong et al., 2021) and patients (Demonaco *et al.*, 2019) in the "fuzzy front end" of their new product development (NPD). Consequently, the NPD process can be considered as a continuous interaction between internal actors and external stakeholders. According to (Caloghirou, Kastelli and Tsakanikas, 2004, p. 29) both internal capabilities and openness towards knowledge acquisition and knowledge sharing are important for upgrading innovative performance. In addition, a successful innovation process requires firms' capability to interact between internal employees and external contributors and set up an active and continuous value co-creation. As a result, the Schumpeterian model of the lone entrepreneur bringing the new product to the market is superseded by an active collaboration of different actors in an iterative NPD process to exploit the new idea and realize market success (Schumpeter, 1934; Urban and von Hippel, 1988; Laursen and Salter, 2006).

Studies show that co-creation is an emerging phenomenon of contribution, where users are the central and essential part of the NPD process (O'Hern and Rindfleisch, 2010; Cooper, 2019). The participation of users has become crucial to realise successful innovation (Cooper, 2019). This kind of co-creation is different from the broader understanding of co-creation, which refers to co-creation experiences (Prahalad and Ramaswamy, 2004) that includes the whole interaction between the customer and the firm, and it focuses on „creating an experience environment in which consumers can have active dialogue and co-construct personalised experience" (Prahalad and Ramaswamy, 2004, p. 8). In our case, co-creation is also different from customer involvement to allow for a single point of idea exchange (Füller et al., 2012). Co-creation is when users actively participate in all phases of the NPD, including idea generation, concept formulation, product development and testing, market diffusion and post-launch activities (Hoyer *et al.*, 2010a).

1.4. The lead user concept

Even though an accurate understanding of user needs is essential for NPD, traditional market research analyses are not reliable in very novel products or rapidly changing product categories like in the high-tech industry. The input of users selected by the traditional market analysis has an important limitation: their insight into new product needs and solutions is restricted to the users' real-world experience. It means that users who apply a product in a familiar way are strongly blocked from using the product in a novel way (Duncker, 1945; Birch and Rabinowitz, 1951; Adamson, 1952). Additionally, individuals who are familiar with a complex problem-solving procedure are unlikely to offer a more direct and simple method when it is appropriate (Luchins, 1942). Furthermore, the more recently a product is used in a familiar way, the more difficult users apply it in a novel way. This phenomenon refers to the notion of the “functional fixedness” of users (Adamson and Taylor, 1954). In addition, the success of market research is influenced by the users’ prior experience, which does not influence the likelihood of achieving success in solving problems, because prior experience is limited to a solution that is appropriate to the present problem (Allen and Marquis, 1964). In addition, users are unable to evaluate novel product attributes which are outside of their real-world experience (Silk and Urban, 1978; Shocker and Srinivasan, 1979; Roberts and Urban, 1988).

Table 1.1. Boundaries of ordinary users to innovate

Insights	**References**
subjects who use a product in a familiar way are strongly blocked from using the product in a novel way (blocking effect of functional fixedness)	Duncker, 1945; Birch and Rabinowitz, 1951; Adamson, 1952
an individual who is familiar with a complex problem-solving procedure is unlikely to apply a more simple problem-solving method even though it would be appropriate	Luchins, 1942
the more recently a product is used in a familiar way, the more difficult users apply it in a novel way	Adamson and Taylor, 1954
the success of a problem-solving process is dependent on users’ experience as the solution to the present problem is limited to the solution applied in the past.	Allen and Marquis, 1964
Users are not positioned to evaluate novel product attributes which are outside of their real-world experience	Silk and Urban, 1978; Shocker and Srinivasan, 1979; Roberts and Urban, 1988

Source: own compilation

Based on the above line of argumentation and according to (von Hippel, 1986), typical users chosen by market research are not suitable to consider a difficult problem-solving task of the NPD, which require: 1. identifying the larger **product pattern** wherein the product is embedded as a small component of the system, 2. identification of existing product **usage patterns** in which the new product can be integrated; 3. invent a new usage pattern that contributes to the product; 4. evaluating the utility in the new product with the usage product pattern; 5. estimating how the new usage pattern presented in the new product will compete or fail with existing options. The problem-solving process is very difficult, particularly when typical users with functional fixedness are invited to do so by market researchers. Even though such users express their perceptions and preferences, they do not go beyond their use experience shared through market research.

In sum, typical users in high-tech technology industries are not well-positioned to accurately evaluate novel product attributes that lie outside of their real-world experience. Table 1.1. summarize all prove and constraints of users applied by von Hippel as arguments in his work.

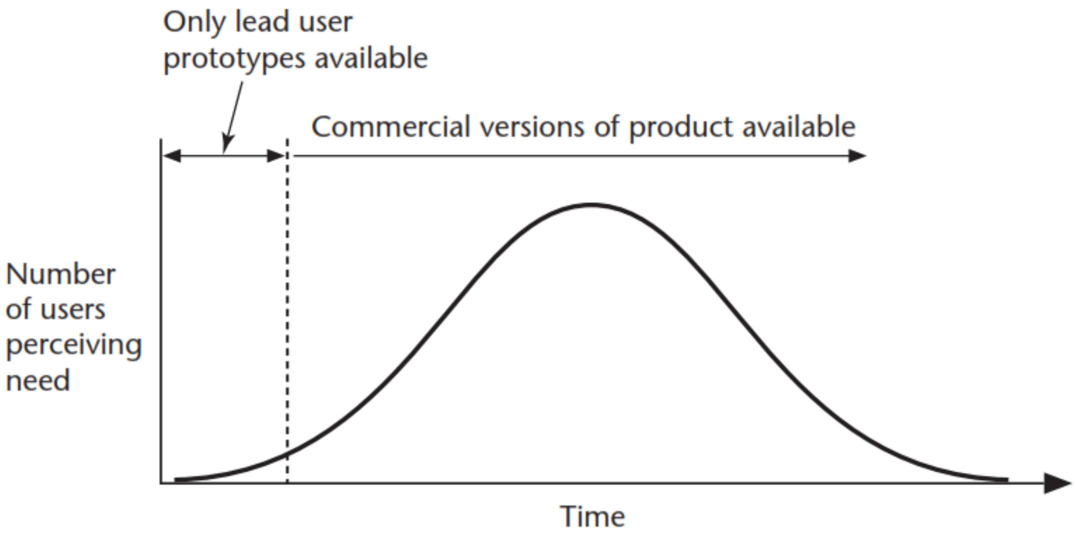
Against all odds von Hippel (1986) states that users are valuable sources of innovation but only lead users with **real-life usage experience.** Only lead users can provide need-, and solution information for new product development and they are in the position to provide accurate future product attributes. von Hippel first defined the term “lead user” and assigned two attributes to them (von Hippel, 1986, pp. 796–798):

- **being ahead of market trend:** “lead users face needs that will be general in a marketplace—but face them months or years before the bulk of that marketplace encounters them” and
- **high expected benefit:** “lead users are positioned to benefit significantly by obtaining a solution to those needs”

Being ahead of market trend

The first attribute state that users who face new needs are in the position to generate innovation that substantially differs from the existing market offerings. Additionally, lead users fulfil also an other important criterion as they are able to recognise needs that most users will need in the future. Lead users are positioned much in advance than the “innovators” on Rogers’s curve of “diffusion of innovation”, as Figure 1.3. shows (von Hippel, 1986; Rogers, 2003; Morrison *et al.*, 2004). In contrast, while the “innovators” have no solutions to fulfil their needs and additionally they have no idea to develop a solution or modify existing products, lead users can recognise needs and have initial ideas and/or solutions to fulfil those needs. According to the original lead user concept if the new product or solution can be attached to leading market trends then the innovation of lead users might lead to financial success (Lilien *et al.*, 2002).

Figure 1.3. The position of lead users on Rogers's curve of diffusion of innovation



Source: (von Hippel, 2005)

High expected benefit

The dissatisfaction with the current market offerings or the mismatch between the expected and available functions or performance of the product trigger lead users' motivation to invest time and effort to initially develop a solution that might eliminate their frustration. Professional users experience difficulties in their daily work, and they encounter the limits of conventional technologies, which force them to search for more workable solutions. Users' investment in innovation is proportional to the expected benefit of the product or solution. The degree of dissatisfaction correlates with the degree of expected benefit from the new development of the solution (Urban and von Hippel, 1988). In contrast with typical customers, lead users are not restricted by "functional fixedness" as they can overcome their real-world experience and they are able to consider the wider (might currently non-existing) use context of the innovation.

If we consider the available (existing) product and needed (non-existing) product as opposite positions then we can also apply the statement of the Swiss psychiatrist and psychoanalyst Carl Gustav Jung to reasoning on lead users' extraordinary driving force to invest into developing the innovative solution: the confrontation of the two positions generates a tension charged with energy and creates a movement out of the suspension between opposites, to a new situation (Jung, 1960). Strong intrinsic motivation also supports creative activities (Csikszentmihalyi, 1988; Füller *et al.*, 2012) that facilitate innovations.

Free revealing

According to empirical studies lead users tend to freely transfer detailed solution information to producer firms as the financial benefit plays no major role in the collaboration with a producer firm (Lüthje and Herstatt, 2004; Ebbing and Lüthje, 2021). "Freely reveals" means that the innovator voluntarily gives up all intellectual property rights and thus information becomes available for the inquiring manufacturer or becomes a public good as all parties have equal access to it. Free revealing is regularly the best practical option available for innovators as users do not need to go through a very difficult, timely and costly innovation protection process (Harhoff, Henkel and Von Hippel, 2003). Additionally, lead users have a very low competitive advantage from exclusive possession of an innovation that they might develop (von Hippel and Sonnack, 1999).

The co-creation is especially preferred in the case of complex high-tech products and when the time-to-market, cost and quality are critical success factors. In some industries like in the case of medical device innovations, various quality guidelines have to be followed, and in most cases, special tools and laboratory environments are required at various stages of the NPD process. These circumstances trigger users to collaborate with producer firms and realize the innovation together in the form of co-creation.

Users making decisions by applying a basic formula as the benefit of freely revealing shall exceed the benefit of keeping the innovation:

$$\text{benefit of freely revealing} > \text{benefit of keeping the innovation}$$

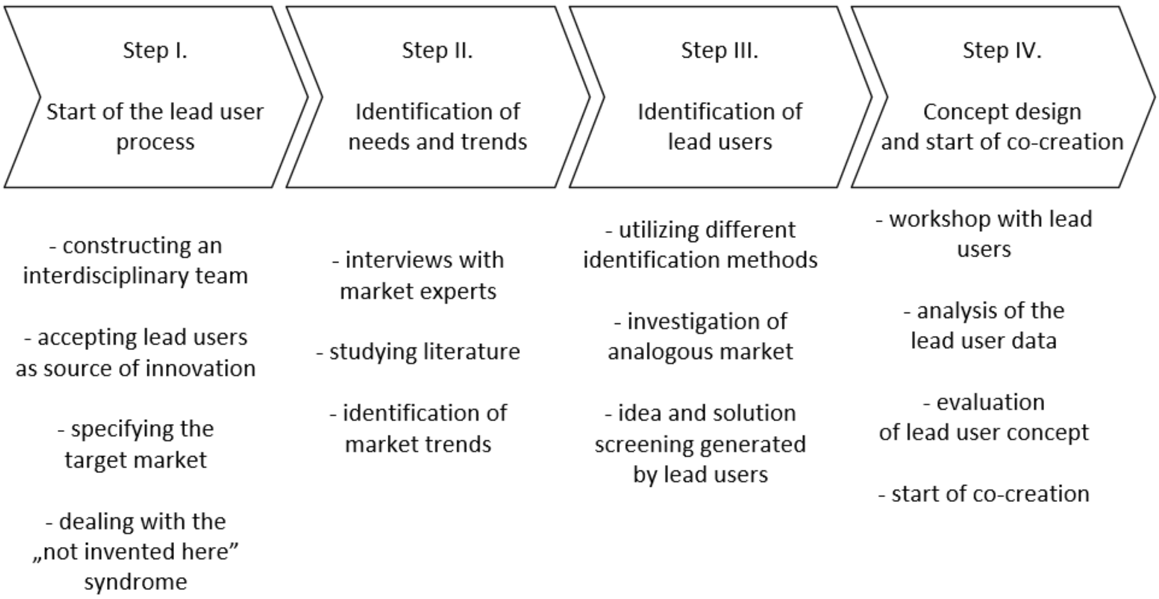
Other studies emphasize the aspect of fairness in the distribution of value between the firm and external contributors (Franke, Klausberger and Keinz, 2013).

In order to identify and involve lead users in the NPD process von Hippel (1986) developed the lead user method, which will be described in the following Section.

1.5. The lead user method

The lead-user method is based on the evidence that lead users: 1. represent a high benefit from realizing a solution to fulfilling their needs by obtaining a solution, and 2. they are at the leading edge of market trends as they experience needs that will be later experienced by the majority of users in that marketplace (Franke, von Hippel and Schreirer, 2006). The traditional lead user method (von Hippel, 1986) was further adjusted based on the collected experience over time. In my dissertation, I apply consistently a later adoption of the lead user method from (Churchill, von Hippel and Sonnack, 2009) as this implementation considers a more detailed process of lead user involvement in the NPD process. The method consists of four major steps, including 1. start of the lead user process, 2. identification of needs and trends, 3. identification of lead users, and 4. concept design as Figure 1.4. shows.

Figure 1.4. The developed lead user method



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Start of the lead user process

The first step refers to the decision of the firm to start an innovation project based on the lead user approach. Product managers must cope with the challenge of dealing with lead users and accept that they are an important source of innovation. A further task in this step is to identify a dedicated market context where the innovation will diffuse. In this stage, an interdisciplinary team shall be constructed which might contain different professionals including product development, production, sales, and marketing. Effectively managing lead users' ideas at the fuzzy front end of the innovation process is one of the most important and challenging tasks for innovation managers. Consequently, the proper composition of the interdisciplinary team is essential to judge an idea to select and transfer for product development (Kim and Wilemon, 2002). The team have to accept the concept that the product is invented outside of the corporate boundaries (not invented here syndrome), which might be a critical and complicated challenging task for innovation managers (Katz and Allen, 1982).

Identification of needs and trends

In the second step "one must identify the underlying trend on which these users have a leading position" (von Hippel, 1986, p. 798). In contrast with conventional customers, lead users are not restricted by the actual use context, and they are probably familiar with needs that will become general on the market in the future. Consequently, the identification of market trends is crucial in which lead users have a leading position. In order to identify trends firms might exploit different sources of information including primary market research, secondary information (academic studies, internet, databases) or conducting interviews with market experts might be valuable.

Identification of lead users

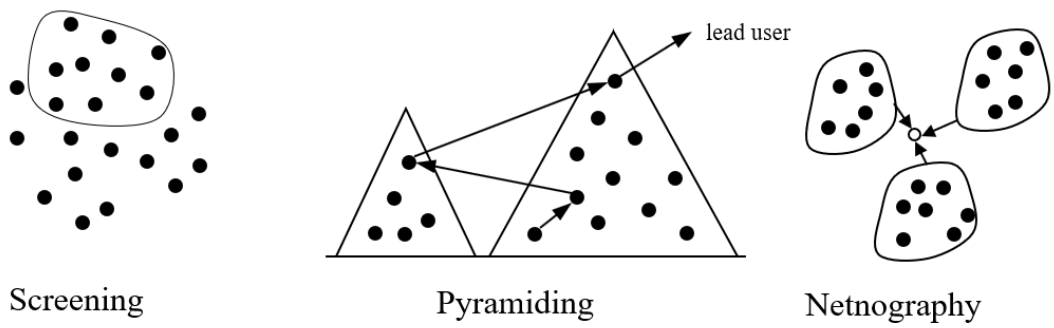
Once one or more market trends are identified that offer promising new product development opportunities, firms start to search for lead users who are "at the leading edge of each identified trend related to a new product needs" and "expect to obtain a high benefit from solutions to those needs" (von Hippel, 1986, p. 798). The first indicator refers to lead users' leading position concerning the identified trend in the previous step. The second criteria suggest that users are dissatisfied with the current market offerings as there is a mismatch between the expected and offered functions or performance. In the case of high dissatisfaction users might start to develop their own solutions for their own use. There are three basic methods are available to effectively identify lead users.

The first is a quantitative process called the screening approach. The basic idea behind it is to consider a large set of samples that probably contains all lead users the firm intends to find. Users are asked through a quantitative survey, questionnaire (Lüthje and Herstatt, 2004) or telephone interview in case of a small set of users. The questions refer to the two main lead user attributes of "ahead of market trend" and "high expected benefit" and their innovations (Urban and von Hippel, 1988).

The second pyramiding method starts with a small number of in-depth interviews wherein participants are asked about a known user who might experience new needs and also develop a solution to fulfil those needs. These informal references might be helpful in identifying lead users only in a community that is well-connected (Hinsch, Stockstrom and Lüthje, 2014; von Hippel and Kaulartz, 2021) mainly in the business-to-business context. Pyramiding is suitable to discover analogous markets and find lead users in other market segments. Analogous markets might offer a benefit as the applied technology of one market field might lead to innovation in an other market segment (Su, Chen, *et al.*, 2021; Zhang *et al.*, 2022)

The third process called netnography (made up of internet and ethnography) is a systematic analysis of online social networks. It is based on the evidence that users express their underlying needs and market implications (Belz and Baumbach, 2010). The process is recommended to combine with the screening approach which consists of four steps including, 1. identifying the target community, 2. collecting and analysing data, 3. interpreting data, 4. informing individuals about the usage of their data in the analysis. Figure 1.5. shows the different lead user identification processes.

Figure 1.5. Different lead user identification approaches



Source: own compilation

According to von Hippel (1986), there are three important complexities of lead user identification. Firstly, proper lead users might not be available within the market context investigated by market research. They might be users of competitors, or they are completely outside of the investigated industry. For example, a user in the aerospace industry might be a lead user in the car industry based on the evidence that the aerospace firms are willing to invest more than car producer firms in improvements of product attributes or in the realisation of radically new ideas. The applied improvements or innovations could be radically new in other industries. Secondly, lead users are not restricted to the proposal of radically new product ideas as they can provide valuable insights for a single or some product attributes. The third complexity refers to users' benefit from the solution which might have been fulfilled and the unmet need might not exist anymore. Even though these users are lead users and valuable sources of innovation it is difficult to identify them through market research.

Studies state that the theoretical base of the identification processes is rather weak and almost no empirical evidence is available about the performance of the identification processes. Lack of indicators exist related to the performance of the different search methods like search time, search cost and effectiveness of the processes as identified lead users (Lüthje, Lettl and Herstatt, 2003; Lüthje and Herstatt, 2004). The described identification process does not offer a solution in the case when users get interaction with producer firms to share their innovative idea or solution.

Concept design and the start of co-creation

As lead users are in the position to obtain high benefits from the solution to their needs, it is reasonable that lead users invest time, cost and effort to solve that problem. The problem-solving activity might be realized in new product attributes, modelling the new solution, or building initial prototypes that are responsive to their needs. The analysis of the proposed solution takes place in a workshop where the lead user proposal is judged. The analysis and the evaluation of the proposed solution are not straightforward as lead users typically do not precisely face the same needs as the innovators on Roger's curve. In the industrial market, the evaluation is based on economic grounds, when users decide based on the cost-benefit calculation. In the instance of consumer goods the evaluation of lead user needs and proposed solutions considering the future market is not so simple (von Hippel, 1986).

2. Problem statements

2.1. Facing uncertainty in the selection process of proper lead users for co-creation

Involving the right users in the NPD process is particularly challenging as the contribution of individuals varies strongly because their personal characteristics differ significantly (Lettl, 2007a; Füller *et al.*, 2012). While the lead user method aims to identify lead users based on their two general attributes of 'ahead of market trend' and 'high expected benefit', it does not consider explicitly the personal characteristics of the users. Consequently, the identification process of the method does not determine lead users' ability for successful co-creation with producer firms.

Scholars state that success in innovation "can only be achieved if the right number of the right people are prepared to collaborate with each other" (Boer, Kuhn and Gertsen, 2006a, p. 9). "Selecting the right user profiles, helps developers to set priorities and design with the most important groups of users in mind" (Abrell, Benker and Pihlajamaa, 2017, p. 9). Furthermore, studies stress the importance of selecting the right user profiles for product development (Gruner and Homburg, 2000a; Schweitzer, Gassmann and Rau, 2014; Abrell *et al.*, 2016; Abrell, Benker and Pihlajamaa, 2017).

Scholars investigate lead users' personal characteristics in different industrial and consumer contexts and related to various products. They found various user characteristics such as imagination capabilities, openness to new technologies, high level of expertise and technological competencies (LaBahn and Krapfel, 2000a; Lettl, 2007a; Hoffman, Kopalle and Novak, 2010; Gürkan, 2014). Schreier and Prügl (2008) found that use-knowledge, product familiarity, locus of control and innovativeness are important antecedents of lead userness. Other studies underline the importance of tacit ("local") knowledge (Lüthje, 2004a; Lüthje, Herstatt and Von Hippel, 2005). Füller, Jawecki and Mühlbacher (2007) find a positive impact of willingness, task motivation, creativity components, and product-relevant knowledge. Faullant, Erich J Schwarz, *et al.* (2012) state that individuals' creativity and personality play an important role in the determination of lead userness.

In other words, improper or ostensible customers with missing essential personal characteristics might lead to an unsuccessful new product development process (Schemmann, Chappin and Herrmann, 2017) and thus end up in failed innovation (Scaringella, 2017).

As the personal characteristics of external contributors influence the success of the co-creation, therefore the proper understanding of lead users' characteristics and their impact on the success of the NPD process are essential to select appropriate co-creators. The relevance of the problem is also underlined by the evidence that right lead users facilitate the successful collaboration between the external contributor and internal employees (engineers, product owners, etc.).

Even though published peer-reviewed papers (details are in Chapter 4.2) investigate the human side of lead users, the examinations are performed in different contexts (industrial and consumer), investigate various types of collaboration (idea exchange, partial involvement into NPD), and interpret co-creation in various senses. In order to gain a comprehensive overview of the existing knowledge related to the personal characteristics of lead users we carried out a systematic literature review (SLR) by answering the followings research question:

> **RQ1: What lead users' personal characteristics should be accounted by a decision maker in the selection process of lead users by considering each stage of the NPD process and the differences between the consumer and industrial segments?**

2.2. Considering the level of lead users' involvement in the NPD process

The research result of the first article demonstrated that published articles investigate lead users' personal characteristics mainly related to the fuzzy front end of the NPD process. The findings of our review shed light on a research gap because as stated in point 1.3. the co-creation is regarded as a process wherein users are the central and essential part of a new product development (Cooper 1993; O'Hern & Rindfleisch 2010). In such collaboration, the participation of users is not limited only to the idea generation phase as they actively participate in the idea generation, concept formulation, product development and test, market diffusion and post-launch activities (Hoyer et al, 2010).

The participation of lead users in the whole process is especially important to exploit their need-, and solution knowledge by considering the fact that lead users' knowledge is likely to be tacit (von Hippel, 1998; Dreyfus, 2004; Venesz, Dőry and Raišienė, 2022) and therefore "sticky" (Lüthje, Herstatt and Von Hippel, 2005), and in addition, the articulation of such "personal knowledge" is difficult (Polanyi, 1958). If the participation of lead users is restricted only to the idea generation phase, then it is very challenging or might be impossible to understand lead users' need-, and solution knowledge by the producer firm in the initial workshop (Churchill, von Hippel and Sonnack, 2009) or by applying different online tools (Franke and Hippel, 2003; Piller and Walcher, 2006).

Our SLR demonstrated among other conclusions that a lack of academic literature is available that investigates the required level of lead users' involvement in various stages of the NPD, and additionally how different characteristics influence the success of the new product development. In order to fulfil this research gap, and to improve our understanding of the impact of personal characteristics of lead users in different stages of the NPD process, we formulated the following research questions:

RQ2: How comprehensively does a lead user need to be involved in the co-created NPD process?

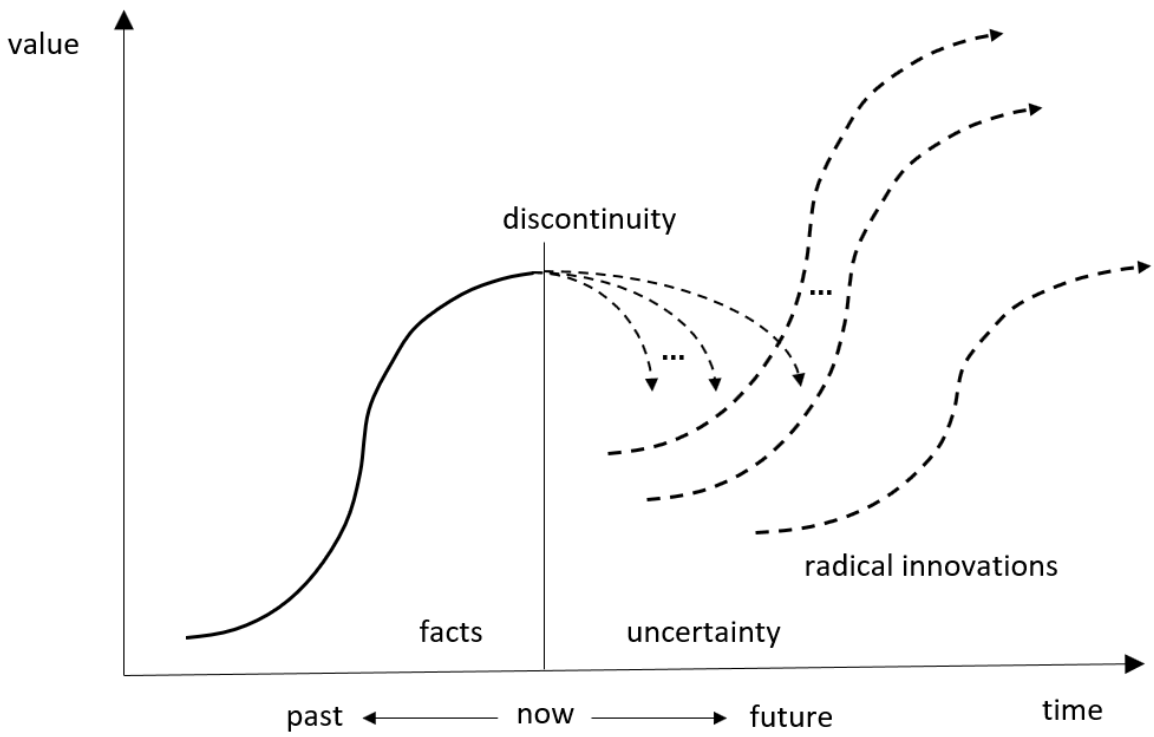
RQ3: How do the different personal characteristics of lead users impact the success of the NPD?

The research employed the results of the first article namely the lead user cognition method, which refers to the cognition process of the innovation manager during the selection process of lead users. As the partial method required dedicated settings where the results can be interpreted, we applied it in the context of medical device innovations.

2.3. Difficulty in implementing into practice the two lead users' basic attributes

Selecting lead users based on their first general characteristic of 'ahead of market trend' "one must identify the underlying trend, on which these users have a leading position" (von Hippel, 1986, p. 798). Von Hippel state in the same paper that the existence of formal methods ranging from the intuitive judgement of experts to simple trend extrapolations, the "trend identification and assessment remains something of art" and additionally "these perceptions may not be consistent over time" (ibid). Empirical studies emphasize also that it is difficult to select reliable information sources and prioritize pieces of information especially when the knowledge and experience of the experts are highly heterogeneous (Lüthje, Lettl and Herstatt, 2003; Lüthje and Herstatt, 2004). Furthermore, the identification of trends might mislead the management in case of radical innovations. This is based on the argument, that in history in the case of radical innovations like the X-ray machine, statoscope, antibiotics, cardiac defibrillator etc. there were no existing trends to identify. Market researchers are familiar with existing trends by taking into account their experience collected in the past (facts), but they might face uncertainty in future market trend prediction (Figure 2.1.). Consequently, in reference to the above reasoning, it might be difficult to predict market trends accurately and thus we concluded that it is uncertain to select lead users based on their general attribute of "ahead of market trend". Figure 2.1. demonstrate how the successive "diffusion of the innovation curves" (Rogers, 2003) follows each other. The uncertainty at the point of "now" related to the future represents our limited knowledge about the shape of the existing and future shape of the "diffusion of the innovation curve".

Figure 2.1. Future trend prediction: uncertainty



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The second lead users' general characteristic of "high expected benefit" refers to the benefit by obtaining the solution. Despite the evidence that some users developed most of the commercially successful product innovations (von Hippel, 1986), empirical studies show that the identification process of lead users is rather weak (Lüthje and Herstatt, 2004) based on the unmeasurable manner of "high expected benefit".

In order to eliminate the weakness of the two general characteristics of lead users and additionally link our research results (new knowledge) to the two basic attributes of lead users (existing knowledge) we set the following research question:

RQ4: How can the identified personal elements be linked to the general characteristics of lead users as "ahead of market trend" and "high expected benefit"?

While RQ1 is worked out in the first research paper (Chapter 4), RQ2, RQ3 and RQ4 are answered in the second research paper (Chapter 5).

3. Research design

This chapter presents the factors of personal motivation that inspired the author to start his PhD research. The overview of the research design of both papers as well as the roadmap of the Chapters aims to provide a better understanding of how the Dissertation was planned and conducted.

3.1. Motivation

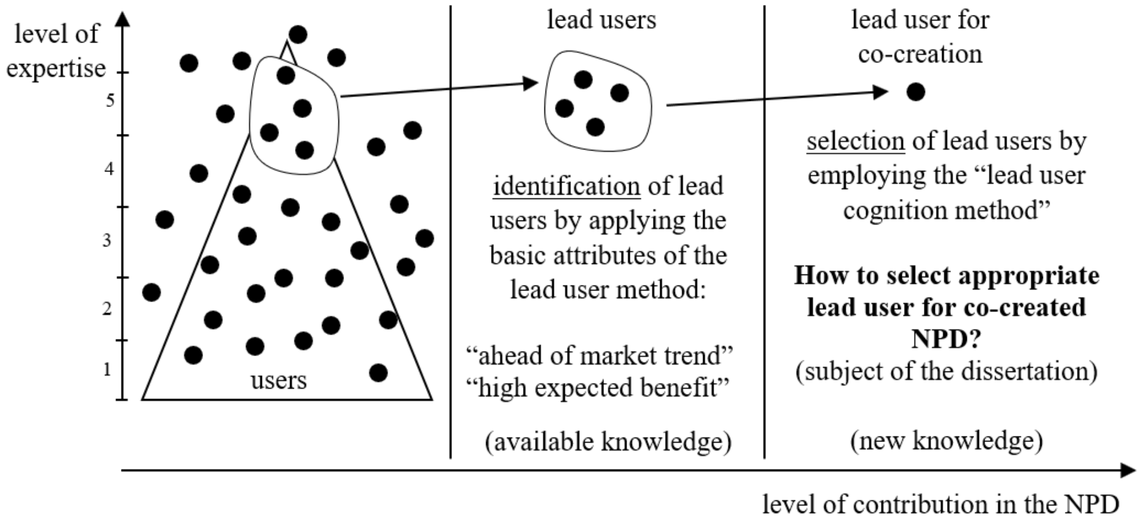
The motivation is obtained during the author's professional activity at the firm with the core business of embedded hardware and software development and production. The company intended to involve users beyond the corporate boundaries in its new product ideation process to exploit the product experience and the use-knowledge of external users. Forcing the idea of open innovation was based on the evidence that users possess deeper product-related "need and solution knowledge" than product engineers employed by the organisation. The firm started to apply the lead user method to identify and involve such promising external users in the co-created NPD process. As the company focused on the development of medical devices the involved users were mainly practitioners from different medical fields.

The lead users concept and method proposed different identification approaches to find the right users based on their two attributes of " ahead of market trend" and "high expected benefit. While the theory was promising, the implementation into practice went not smoothly. The first difficulty was related to the unpredictable status of future trends, especially in the case of radical innovations. The second problem was related to the unmeasurable manner of "high expected benefit" of users. Furthermore, the author discovered that each user possesses different personal characteristics (knowledge, skills, and motivation) which have a different impact on the technical and market success of the new product. As these "human factors" are not managed by the lead user method, the author's attention turned to the personal characteristics of the appropriate lead users. At this time he assumed that the brilliant idea itself is useless if the contributor does not possess proper personal characteristics for the co-created NPD.

This experience triggered the author to investigate further the phenomenon. Thus, he enrolled on the SzEEDSM Doctoral Program and started his investigation with a systematic literature review of the existing academic knowledge. He was interested in different lead users' characteristics related to the industrial and consumer market segments and at different stages of the NPD process. Based on the first phase of his academic activity he continued the investigation in the field of medical device innovations by carrying out case study research at five medical device developers and manufacturer companies. The research resulted in the personal profile of the appropriate lead user in the dedicated field of medical device innovations. The research result provided significant evidence to extend the original lead user method with an embedded partial method called the "lead user cognition method" as well as providing managerial contribution by the definition of signals to select the right contributors. The practical contribution of the research is especially meaningful for decision-makers during the lead user selection process as the concluded signals have a high level of practicability.

Figure 3.1. aims to demonstrate the research problem of the dissertation. The left side of the figure shows the principle of lead user identification based on the traditional lead user concept (available knowledge). This method set two criteria for the identification as "ahead of market trend" and "high expected benefit". The right side of the figure demonstrates the result of the dissertation (new knowledge) which provides a partial method named "lead user cognition method" that enables a decision maker to select appropriate lead users for the co-created NPD and thus ensure the technical and market success of the new product.

Figure 3.1. Demonstrating the available and new knowledge



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The research results were presented at the leading conferences including the Open and User Innovation (OUI) Conference in Aachen (2021), CINet Conference in Denmark (2022), ISPIM Conference in Goeteborg (2022) with excellent double-blind review results. The creator of the lead user concept Eric von Hippel at the OUI Conference appreciated the research idea and also the “lead user cognition method”. Fortunately, he invited the author for a personal discussion about his research which helped him to advance further my research.

3.2. Design of the research papers

The Dissertation consists of two research papers including a systematic literature review (SLR) and a case study.

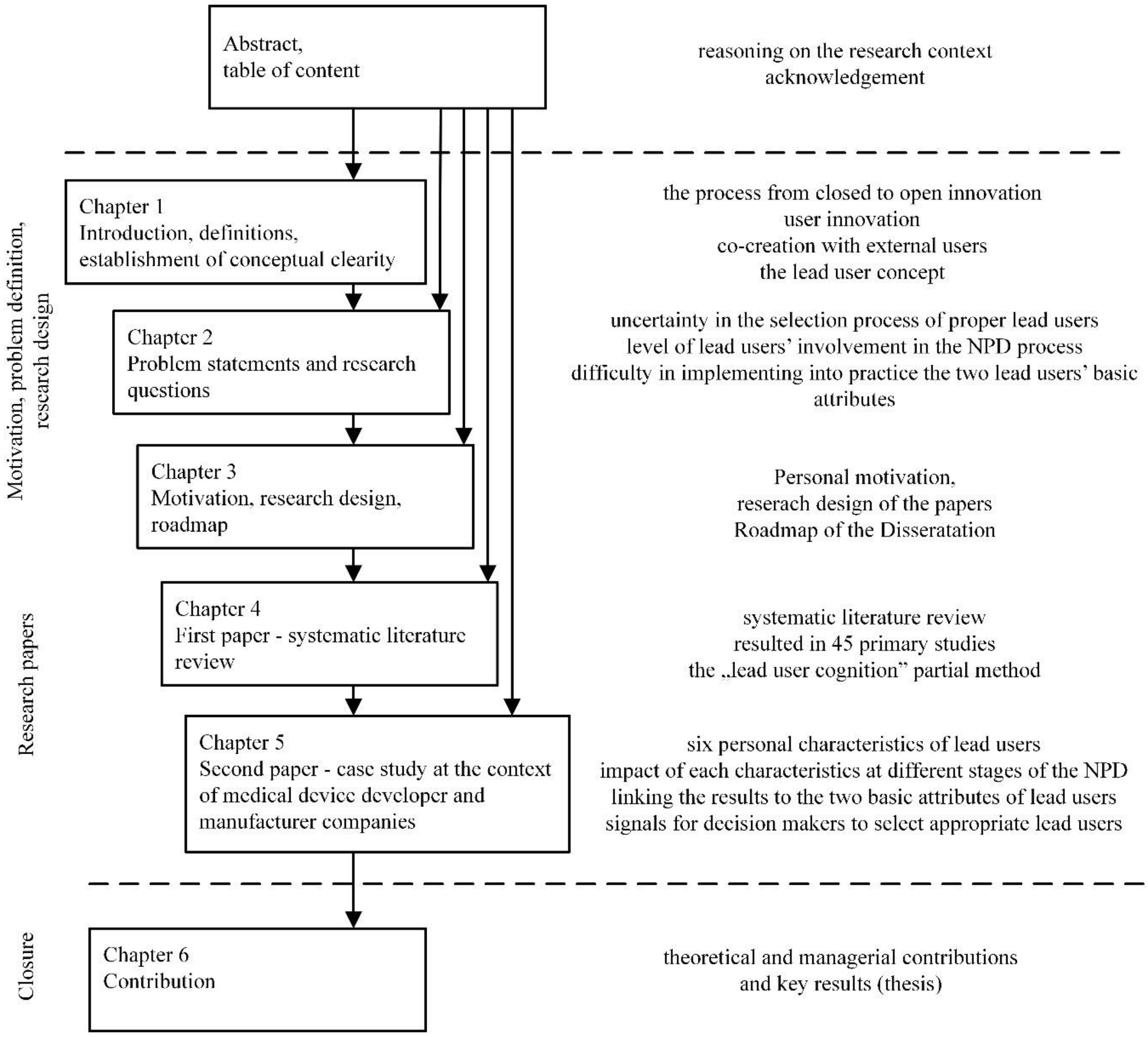
The research design of the SLR was based on the main research aims of the SLR including 1. creating a narrow research question and systematically searching, analysing and synthesising research results of the published literature between 2000 and 2020, taking into consideration the value and accuracy of the studies; 2. reporting findings at different stages of the NPD process separated into consumer and industrial contexts; 3. identifying research gaps for further research, which requires additional investigation. To reach these aims and also perform effective research work with appropriate rigour and consistency, the research guidelines were followed proposed by Kitchenham and Charters, 2007; Grant and Booth, 2009; Booth (2012). A review protocol was established to minimize the possibility of researcher bias and avoid an analysis driven by the researcher’s expectations (Kitchenham and Charters, 2007). The review protocol contained all elements of the review method, including the description of the research background and research question, inclusion and exclusion criteria, automatic and manual search strategy, quality assessment method, data extraction and synthesis of the primary studies.

The case study applied abductive reasoning to eliminate the weaknesses of inductive and deductive reasoning by using both induction and deduction cyclically. The case companies were selected by employing theoretical sampling that enabled the clear pattern recognition of the focal phenomenon that provided a strong base for theory building (Eisenhardt and Graebner, 2007). The applied systematic combining resulted in a simultaneous and gradual evolvement of the theoretical framework, fieldwork and case analysis which was a “back and forth” process between the empirical data and theory that allowed a deep understanding of the theory and the phenomena. The systematic combining collaborated with the applied abductive reasoning through a highly iterative process of theory and practice that co-evolved the initial propositions and the conceptual framework. The interviews were conducted in three phases. In the first phase, the aim was to collect and analyse interview data, in the second phase to verify the interpretations of the collected data from the interviews, and in the third phase, the goal was to embed the results into an existing theoretical framework.

3.3.Roadmap of the Dissertation

To share the research design and the result of the Dissertation in a convenient way Figure 3.2. provides a roadmap that highlights the purpose and content of each Chapter and their relation to each other. The roadmap also aims to facilitate the right understating of the Dissertation regardless of the readership of academicians as well as practitioners.

Figure 3.2. The roadmap of the Dissertation



Source: own compilation

4. Characteristics of Lead Users in Different Stages of the New Product Development Process: A Systematic Review in the Context of Open Innovation (first paper)

Paper reference

Venesz, B., Dőry, T. and Raišienė, A.G. (2022) 'Characteristics of Lead Users in Different Stages of the New Product Development Process: A Systematic Review in the Context of Open Innovation', *Journal of Open Innovation: Technology, Market, and Complexity*, 8(1). https://doi.org/10.3390/joitmc8010024 (published)

4.1. Abstract

Despite the promising ideas of lead users, the success rate of the open innovation process remains low if no proper personal characteristics are attached to the external contributor. Knowledge about the essential characteristic elements of lead users is crucial to select the right lead users in the early stage of the NPD. By filling the research gap, we performed a systematic literature review about the required personal characteristics of lead users. The resulting 45 studies demonstrated that diverse characteristics are required in different stages of an NDP which vary in the consumer and industrial context. According to our research results, we made a contribution to the theory by extending the lead user method in the form of a partial theory. We also found that in the case of incremental innovations, companies apply their technical knowledge and do not require additional expertise from users, while in the case of radical innovations, firms only involve external users with high technological competencies in the development stage of the NDP. We identified similarities and differences of the required lead users' personal characteristics in the consumer and industrial contexts. Thus, our study provides a better awareness for business leaders on the selection of lead users for their NPD process, reducing the time-to-market ratio of the product and increasing profit.

Keywords: open innovation; lead user; personal characteristics; new product development; co-creation; systematic review

4.2. Introduction

Open innovation supports corporate growth and profitability. Firms are increasingly opening their boundaries and applying various methods to identify user innovations (Shrestha, Krishna and von Krogh, 2021) and tap users' product knowledge and experience (Chesbrough, 2003; Enkel, Bogers and Chesbrough, 2020). Successfully innovating firms involve users (Bradonjic, Franke and Lüthje, 2019; Franke and Lüthje, 2020), customers (de Jong *et al.,* 2021) and patients (Demonaco *et al.,* 2019) in the "fuzzy front end" of their new product development (NPD). Ref. (von Hippel, 1986) states that average users are not suitable for developing novel product attributes because they cannot accurately determine future market needs. Only leading-edge users with real-life usage experience can provide accurate information on the needs for product development. Quality information from lead users (Churchill, von Hippel and Sonnack, 2009) and their systematic design freedom (von Hippel and Cann, 2021) results in better product development. von Hippel first defined the term lead user, then assigned two main attributes to identify them: "lead users face needs that will be general in a marketplace—but face them months or years before the bulk of that marketplace encounters them, and lead users are positioned to benefit significantly by obtaining a solution to those needs" (von Hippel, 1986) (p. 13). The high expected benefit and the superior trend position are also strong predictors for co-creation (Globocnik and Faullant, 2021a).

The lead-user method aims to identify and involve lead users to the NPD process as they are "at the leading edge of each identified trend in terms of related new products and process needs" and they "expect to obtain a relatively high 'net benefit' from solutions to those needs" (von Hippel, 1986) (p. 798). All later adoptions of the lead user method contain these two crucial attributes of lead users (von Hippel, Thomke and Sonnack, 1999; Lilien *et al.*, 2002; Olson and Bakke, 2004; Eisenberg, 2011). The adaption of the lead user method by (Lüthje and Herstatt, 2004) consists of the following four steps: 1. start of the lead user process, 2. identification of needs and market trends, 3. identification of the lead user, 4. concept design and the start of co-creation. According to scholars, it is challenging to determinate lead users in the fuzzy front end of the NPD process (Lüthje, 2004a; Schuurman, Mahr and De Marez, 2011; Sänn and Baier, 2012) even with the existence of multiple identification methods (Belz and Baumbach, 2010; Su, Chen, *et al.,* 2021; Su, Zhang, *et al.*, 2021).

While the lead-user method is suitable for the identification of lead users based on the two main attributes of 'ahead of market trend' and 'high expected benefit', it does not consider explicitly the personal characteristics elements of lead users, such as users' knowledge, motivation, skills, behaviour, experience, betweenness centrality, attractiveness, etc. Studies emphasize that the lead users' personal characteristics are crucial for successful co-creation. According to (Füller *et al.*, 2012), the contribution of individuals to the co-operation process varies strongly; therefore, the proper selection of lead users plays a critical role. This is in line with the findings of (Lettl, 2007a), which state that the characteristics of users differ significantly from the user type, typically involved in conventional research. Scholars emphasize the importance of selecting the right user profiles for the development process (Gruner and Homburg, 2000a; Abrell *et al.*, 2016; Abrell, Benker and Pihlajamaa, 2017). The authors highlight the role of 'the human factor' and state that the synergy in innovation "can only be achieved if the right number of the right people are prepared to collaborate with each other" (Boer, Kuhn and Gertsen, 2006a, p. 13).

An increasing number of studies investigate lead users' personal characteristics. Ref. (Lettl, 2007a) underlines the importance of imagination capabilities, openness to new technologies, high level of expertise and technological competencies. According to (Schreier and Prügl, 2008a), consumer knowledge, use experience, locus of control and innovativeness are important antecedents of lead userness. Refs. (Lüthje, 2004a; Lüthje, Herstatt and Von Hippel, 2005) highlight the importance of "local" (tacit knowledge) information. Ref. (Füller, Jawecki and Mühlbacher, 2007) finds a positive impact on willingness, task motivation, creativity components, and relevant product knowledge. Ref. (Faullant, Erich J Schwarz, *et al.*, 2012) states that individuals' creativity and personality play an important role in the determination of lead userness. Ref. (Schweitzer, Gassmann and Rau, 2014) finds that managers shall pay attention to the selection of the right users for idea generation of an innovation process. Ref. (Schemmann, Chappin and Herrmann, 2017) emphasizes that improper customers may appear to offer benefits such as experience sharing and improvement suggestions; however, their value is misleading due to the missing vital personal characteristics. Ref. (Scaringella, 2017) describes the case of failed innovation by ostensible users with a lack of essential characteristics.

Studies show that co-creation is an emerging phenomenon of contribution where customers are the central and essential part of the NPD process (O'Hern and Rindfleisch, 2010). The participation of users has become crucial to realize successful innovation (Cooper, 2001). This kind of co-creation is different from the broader understanding of co-creation, which refers to co-creation experiences that include the whole interaction between the customer and the firm, and it focuses on “creating an experience environment in which consumers can have active dialogue and co-construct personalized experience” (Prahalad and Ramaswamy, 2004, p. 8). In our case, co-creation is also different from customer involvement to allow for a single point of idea exchange (Füller *et al.*, 2012). Co-creation is when lead users actively participate in all phases of the NPD, including idea generation, concept formulation, product development and test, market diffusion and post-launch activities (Hoyer *et al.*, 2010a).

As the personal characteristics of lead users have a high impact on the success of the open innovation process, the clear understanding of the required personal characteristics' elements at different stages of the NDP is therefore crucial for managers to select the proper lead users for their NDP process. The relevance of the problem is judged by the evidence that managers aim to select the right lead users for their NPD depending on the level of lead user involvement in the NPD. In the case of high-level involvement, decision-makers aim to reduce the gap between different professional backgrounds, and different points of view between external contributors (lead users) and internal employees (engineers, product owners, etc.). The knowledge about the lead user characteristics in different stages of the NPD is relevant for making the right decision during the selection process of lead users.

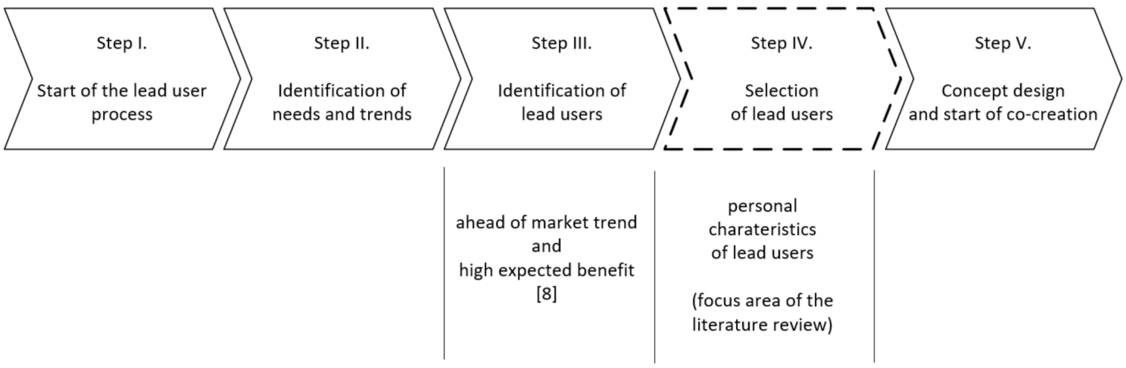
Scientific articles usually investigate only one or some personal characteristic elements of lead users in a dedicated market context (consumer or industrial). Insights into what is important at different stages of the NPD are very scarce. Although these publications are of great scientific value, we found no study, which comprehensively reviews the published peer-reviewed papers related to the personal characteristics of lead users in different stages of the NPD process. In order to fulfil this research gap, we carried out a systematic literature review (SLR) and report the findings of our study.

The authors defined three aims of the systematic literature review (SLR). The first goal is to create a narrow research question and systematically search, analyse and synthesize research results of the published literature between 2000 and 2020, taking into account the value and accuracy of the studies. The second aim is to report findings at different stages of the NPD process separated into consumer and industrial contexts, while the third one is to identify research gaps for further research, which requires additional exploration and investigation. To reach the above objectives, the following research question is formulated:

RQ: What personal characteristics of lead users' managers need to consider in the selection process of lead users by considering each stage of the NPD process and the differences between the consumer and industrial segments?

We considered the lead user method as a basic concept to identify and involve lead users in the NPD process. We have assumed the missing link of the step of 'selection of lead users based on their personal characteristics in the lead-user method between the steps of 'identification of lead user' and 'start of co-creation' (see Figure 4.1.). Step IV shows the clear focus of the SLR and determines the contribution of our research results to the lead-user method.

Figure 4.1. Extended lead-user method concerning the focus area of the literature review



Source: own compilation

The research is also driven by the intrinsic motivation of the authors as one of them spent more than a decade in the high-tech industry as a manager and found that users' brilliant ideas are valueless and no significant commercial success could be achieved if no proper personal characteristics are attached to the lead users during the open innovation process.

To perform our work effectively, we followed appropriate rigour and consistency and used an explicit and reproducible method. In the study, the authors followed the guidelines proposed by Kitchenham and Charters, 2007; Grant and Booth, 2009; Booth (2012).

At this point of the study, we would like to make a note about the applied terminology of "customers" and "users". Both expressions are used with identical values. The difference between them is the context in which they are used. In the industrial context, end users (named "users") of a product use the product directly without making a purchasing decision, while users in the consumer context (called "customers") use a product directly along with making also a purchasing decision. We use the term "user" in the industrial context and the term “customer” in the consumer context with an identical values. The following section describes the literature review method, including the assessment criteria, search strategy, study selection process and quality assessment.

The systematic literature review consists of the following sub-elements: 1. identifying the review questions, 2. formulating the research method, 3. defining the inclusion and exclusion criteria, 4. implementing quality assessment and 4. synthesizing the evidence to answer the research questions.

4.3. The Review Method

The review protocol describes and identifies the method to be applied to carry out a systematic literature review. The review protocol is an important step to minimize the possibility of researcher bias and avoid an analysis driven by the researcher’s expectations (Kitchenham and Charters, 2007), and additionally to avoid fuzzy input that tends to lead to fuzzy answers. The review protocol contains all elements of the review method, including the research background and research question, study selection criteria, search strategy, quality assessment, extraction, and synthesis of the primary studies. Taking these factors as a departure, our study reviews the research question and the research background as described above in the previous sections of this paper. The following sub-sections of our study contain the remaining listed elements of the review method.

4.3.1. Inclusion and Exclusion Criteria

The inclusion and exclusion criteria ensure that all selected primary research is pertinent and relevant to the study. The aim of our literature review is to understand the personal characteristics of the lead user, which enables a successful contribution to the co-creation process. Related to this stated research question, the review contains data from journal articles and conference proceedings available in full text, published in English in the identified databases between 2000 and 2020 in the domain of open innovation. The authors have excluded research articles with content unavailable in full text, research published outside of the identified time frame, research without a proper description of data sources and methodologies, studies containing no relevant research results about the lead users’ personal characteristics, and papers containing only secondary research results. Table 4.1. covers all criteria for the literature review:

Table 4.1. Inclusion and exclusion criteria

Inclusion criteria:	Available in full text
	Published between 2000 and 2020
	Written in English
	Related to the research question
	Within the searched domain of open innovation
	Published in the selected databases
Exclusion criteria:	Full text unavailable in electronic form
	Outside of the search timeframe
	Research without the description of data sources and methodology
	No information about lead user characteristics
	Papers with only secondary research results

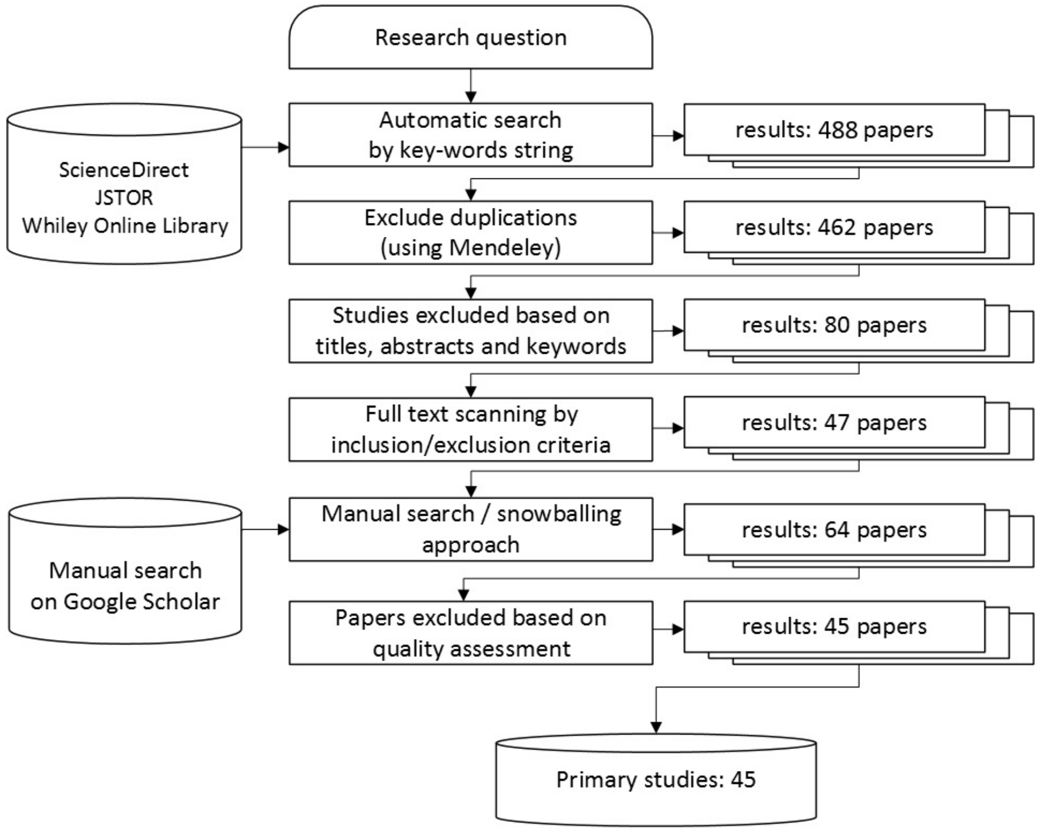
Source: own compilation

4.3.2. Search Strategy

The search strategy involves both automatic and manual searches to explore a broader perspective of lead-user characteristics. The automatic search was an electronic search based on the defined keywords to address the research question of the SLR. Following the recommendation by (Kitchenham and Charters, 2007), we conducted firstly the automated search for primary study references and secondly the manual search. Four online scientific databases were selected as the main sources for the review: ScienceDirect, JSTOR, Scopus and Whiley Online Library. These databases provided the most relevant information for the domain-related lead users' characteristics. The used keyword string with the Boolean applied operators was: "lead-user" and "characteristics" and "new product development" and "innovation". Although the word "co-creation" would theoretically lead to more accurate search results, the authors decided to exclude this keyword from the search string as the search had filtered out the relevant studies. After the first stage of the search process, we applied the manual search and utilized the forward and backward search process to track the references of the primary studies through manual reference scanning, which is the so-called "snowballing" method (Webster and Watson, 2002). This process ensured a relatively complete systematic search, even though the primary search had not resulted in identifying relevant articles. Through the backward search, we manually scanned all the references of the current paper to find relevant studies which had not been found by the automatic search. The forward search found papers which confirmed, applied, extended, and improved the results of the referenced study. We used the Mendeley application for sorting all primarily and manually searched-for studies and removed duplicate studies.

The authors followed the review guidelines recommended by Kitchenham and Charters (2007), which consist of three major parts, including planning, conducting and reporting the review. These stages consist of sub-elements, including 1. formulating the review question, 2. identifying the research method, 3. creating the inclusion and exclusion criteria, 4. performing quality assessment, and 5. synthesizing the evidence to answer the research question. The backward and forward search and automatic search ensure that the systematic literature review is the relatively complete processing of the relevant literature (Webster and Watson, 2002). The flow diagram (see Figure 4.2.) presents both automatic and manual searches as well as the selection process with the search results.

Figure 4.2. Flow diagram of the search and selection process



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4.3.3. Study Selection Process

The automatic search process resulted in 488 papers by utilizing the defined keywords. Four papers were found as duplicates, and they were removed by using the Mendeley application. The exclusion criteria were applied to the remaining 462 papers focusing on the title, the abstract and the keywords of the papers. The aim of this step was to classify studies accurately to eliminate the ones, not in sync with the research question. The process led to 80 studies remaining. The initial automatic search brought about many papers unrelated to the research question. As recommended by Kitchenham (2004), the authors maintained a list of excluded papers at this stage of the selection process. The next step involved reading the remaining studies to apply the inclusion/exclusion criteria, which culminated in 47 papers. Applying the manual and snowballing search methods on Google Scholar and utilizing the quality assessment led to 45 relevant studies.

4.3.4. Quality Assessment

The authors used a generic set of questions to evaluate the quality of each selected primary paper. This refers to a process of weighting the importance of each study when the results and the findings of selected primary studies are interpreted (Kitchenham, 2004). The authors conducted a quality assessment (QA) of the selected primary studies to fulfil the quality and accuracy criteria. Five QA criteria were formulated as Table 4.2. shows.

Table 4.2. List of the quality assessment criteria

QA1:	Does the research investigate users' characteristics?
QA2:	Does the type of cooperation refer to co-creation?
QA3:	Is the market domain accurately defined?
QA4:	Is the research about new product development?
QA5:	Are the research methodology and results accurately described?

Source: own compilation

The quality assessment questions were evaluated in each primary study to strengthen the researchers' confidence in the overall quality of the selected papers. Table 4.3. shows the results of the QA process.

Table 4.3. Results of the paper selection process

Results of the Study Selection Process	Initial Results	Relevant Studies
ScienceDirect	291	16
Scopus	12	0
JSTOR	39	2
Whiley Online Library	146	18
Google Scholar (second stage)	-	9
Summary:	488	45

Source: own compilation

The papers were graded by "high", "medium" and "low" quality rankings. If the paper satisfied the criterion, then it was given a score of 1. If the paper partially satisfied the criterion, it was given a score of 0.5. If the paper did not meet the criterion, it was given a score of 0 (Nidhra *et al.*, 2013). According to the QA criteria and scoring process, the highest possible score is 5 (5 × 1) and the lowest possible is 0 (5 × 0). Studies scored between 4 and 5 were considered high-quality papers, between 3.0 and 3.5 as medium quality and papers with a score of 2.5 as low-quality papers. We identified nine low-quality papers (20%), seven medium-quality studies (16%) and 29 high-quality research articles (64%). QA ratings of each paper are listed in Table 4.4.

Table 4.4. Quality Assessment scores of primary studies.

SID	QA1	QA2	QA3	QA4	QA5	SUM	SID	QA1	QA2	QA3	QA4	QA5	SUM
S1	0.5	0	1	0.5	0.5	2.5	S24	0.5	0.5	1	0.5	1	3.5
S2	1	0	0.5	1	0	2.5	S25	0.5	0.5	1	0.5	1	3.5
S3	0.5	1	0	0	1	2.5	S26	1	0.5	1	0.5	1	4
S4	1	1	1	1	1	5	S27	1	0	1	0.5	1	3.5
S5	1	0.5	1	1	1	4.5	S28	0.5	1	1	1	1	4.5
S6	1	0.5	1	0.5	1	4	S29	1	0.5	1	0.5	1	4
S7	1	1	1	1	1	5	S30	1	0.5	1	0.5	1	4
S8	0.5	0.5	0.5	0.5	1	3	S31	1	1	1	1	1	5
S9	1	0.5	1	0.5	1	4	S32	1	1	1	0.5	1	4.5
S10	0.5	0.5	0.5	0	1	2.5	S33	0	0.5	1	0	1	2.5
S11	1	1	1	1	1	5	S34	0.5	0.5	0.5	0.5	0.5	2.5
S12	1	0.5	0.5	1	1	4	S35	1	1	1	1	1	5
S13	1	0.5	1	0.5	1	4	S36	1	0.5	1	0.5	1	4
S14	1	0.5	0.5	1	1	4	S37	0.5	1	1	0.5	1	4
S15	1	1	1	1	1	5	S38	1	1	0.5	0.5	1	4
S16	1	0.5	1	0.5	1	4	S39	1	0.5	0	0.5	0.5	2.5
S17	1	1	1	1	1	5	S40	1	0.5	1	1	1	4.5
S18	1	0.5	1	0.5	1	4	S41	1	1	0.5	1	1	4.5
S19	0.5	0	1	0	1	2.5	S42	1	0	0	1	1	3
S20	0.5	0.5	1	0.5	1	3.5	S43	0	0.5	1	0.5	1	3
S21	1	1	1	1	1	5	S44	1	0	1	1	1	4
S22	1	0.5	1	0.5	1	4	S45	1	0.5	1	0.5	1	4
S23	1	0	0.5	0	1	2.5							

Source: own compilation

2.5. Data Extraction and Synthesis of SLR

The data extraction form (Appendix A) accurately records all the information that the researchers have obtained from the primary 45 studies. To reduce the chance of bias, the data extraction form has been defined and it includes the following columns: study ID, title and authors, year of publication, the context of the research, key findings, used methodology, countries and regions covered by the research, type of paper, data provider of the study, number of samples and the journal name (Table 4.5.).

Table 4.5. Data extraction for primary studies.

Study ID:	Unique identifier of the study
Title and Authors:	The title and name of the authors of the study
Year:	The year of publication (between 2000 and 2020)
Context:	Identification of the product field (consumer, industrial, mixed, not available)
Key Findings:	The key findings of the paper
Methodology:	The used methodology in the research (quantitative, qualitative, mix)
Country:	The name of the countries covered by the research
Type:	The type of the paper (journal article, conference proceeding, book chapter)
Data Provider:	Name of the source the study was retrieved from
Number of Samples:	Number of samples used in the research
Journal Name:	Name of the journal the study was published in

Source: own compilation

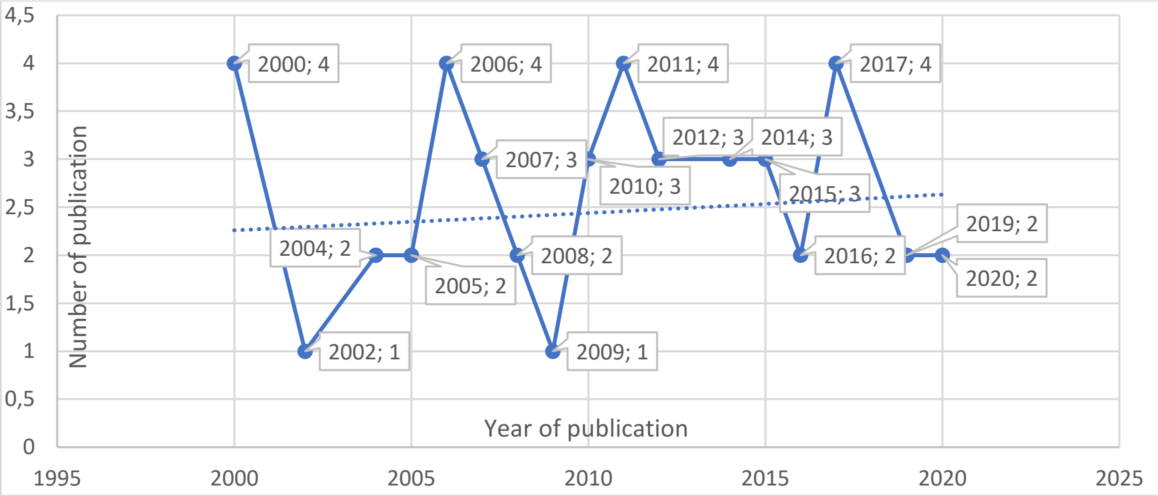
Following the systematic review, 45 papers as primary studies were finally selected that had been published within the investigated research field.

4.4. Research Results

The review comprised 44 journal articles and one conference proceeding which was assessed as a high-quality paper. Multiple methodologies, i.e., qualitative, quantitative, and mixed ones, were applied. Out of the total 45 studies, 26 papers (58%) used quantitative methodology, 18 (40%) utilized qualitative methodology and one study (2%) employed mixed methodology.

Figure 4.3. shows the chronological distribution of the primary studies. The trendline indicates the increasing number of relevant studies related to the research domain of the personal characteristics of lead users.

Figure 4.3. Chronological distribution of the primary studies



Source: own compilation

The SLR resulted in 33 studies concerning the consumer context and 12 studies regarding the industrial domain. Table 4.6. shows the journal names and rankings (source: [www.scimagojr.com, accessed](http://www.scimagojr.com) on 22 December 2021) of the primary studies, indicating the number of studies retrieved from the journal.

Table 4.6. The name and ranking of the journals and the number of studies retrieved.

Name of the Journal	**Ranking**	**Number of Studies**
Creativity and Innovation Management	Q1	8
Journal of Product Innovation Management	Q1	6
R&D Management	Q1	4
Research Policy	Q1	4
Journal of Business Research	Q1	3
Journal of Engineering and Technology Management	Q1	3
Technovation	Q1	3
Information and Management	Q1	2
Management Science	Q1	2
Organization Science	Q1	2
California Management Review	Q1	1
European Journal of Management and Business Economics	Q2	1
International Journal of Innovation Management	Q2	1
Journal of Management Information Systems	Q1	1
Journal of Marketing Research	Q1	1
Marketing Letters	Q1	1
Technological Forecasting & Social Change	Q1	1

Source: own compilation

The new product development process is significantly different in the consumer and the industrial domain (Biemans, 1991; Gruner and Homburg, 2000a). Considering this fact, the authors systematically distinguished the research contexts and separated the elements of personal characteristics in each stage of the NPD process. The characteristic elements of the lead users are shown in Table 4.7. The following sub-sections will provide insights into the personal characteristics of lead users in the subsequent stages of the NPD process: 1. idea generation; 2. concept generation and 3. prototype development and testing by answering the research question.

Table 4.7. Lead user personal characteristics in consumer and industrial contexts.

Stages of the NPD Process	References (Consumer Context)	Consumer Context	Both	Industrial Context	References (Industrial Context)
Development and testing				technical expertise (positive impact)	Lettl, Herstatt and Gemünden, 2006; Lettl, 2007
	Füller et al., 2012; Sadowski, 2017		willingness to experiment and test		Lettl, Herstatt and Gemünden, 2006; Lettl, 2007
				technical expertise (negative impact)	Gruner and Homburg, 2000
				tolerance for ambiguity	Lettl, Herstatt and Gemünden, 2006; Lettl, 2007
Concept Development	Hoffman, Kopalle and Novak, 2010	optimism			
	Hoffman, Kopalle and Novak, 2010	openness to new experience		openness for new technologies	Lettl, Herstatt and Gemünden, 2006; Lettl, 2007
	Hoffman, Kopalle and Novak, 2010	verbal and visual processing styles		interdisciplinary know-how	Lettl, Herstatt and Gemünden, 2006; Lettl, 2007
	Schweitzer et al., 2015	high technological reflectiveness		resources of research	Lettl, 2007; Marchi, Giachetti and de Gennaro, 2011
Idea Generation			KNOWLEDGE AND EXPERIENCE		
	Lüthje, 2004		prior knowledge and experience		Shane, 2000; Lettl, Herstatt and Gemünden, 2006; Gürkan, 2014; Mahr, Lievens and Blazevic, 2014
	Lüthje, Herstatt and Von Hippel, 2005; Schweisfurth, 2017		need and solution knowledge		Lettl, 2007
	Füller, Jawecki and Mühlbacher, 2007; Schreier and Prügl, 2008; Faullant, Erich J Schwarz, *et al.*, 2012		product knowledge, use experience		Lettl, 2007; Marchi, Giachetti and de Gennaro, 2011; Gürkan, 2014; Mahr, Lievens and Blazevic, 2014

Lüthje, 2004; Schreier, Oberhauser and Prügl, 2007; Schweitzer, Gassmann and Rau, 2014		technical knowledge		LaBahn and Krapfel, 2000; Lettl, 2007
		MOTIVATION AND WILLINGNESS		
Füller et al., 2012		intrinsic motivation		Lettl, Herstatt and Gemünden, 2006; Lettl, 2007; Gürkan, 2014
Füller et al., 2009	experienced empowerment		entrepreneurial mindset	Lettl, Herstatt and Gemünden, 2006
Füller, Jawecki and Mühlbacher, 2007	willingness to share ideas		motivation induced by problem	Lettl, 2007
Marchi, Giachetti and de Gennaro, 2011	willingness to collaborate			
Füller, Jawecki and Mühlbacher, 2007	motivation driven by excitement			
Marchi, Giachetti and de Gennaro, 2011	brand identity			
		CREATIVITY AND SKILLS		
Schreier and Prügl, 2008; Hoffman, Kopalle and Novak, 2010; Faullant, Erich J Schwarz, *et al.*, 2012		divergent thinking style		Lettl, 2007
Hoffman, Kopalle and Novak, 2010; Faullant, Erich J Schwarz, et al., 2012; Füller et al., 2012	creativity relevant skills		imagination capabilities	Lettl, 2007
Kratzer and Lettl, 2008; Kratzer et al., 2016	betweenness centrality			
Kratzer and Lettl, 2008	age and cognitive capacity			
		BEHAVIOUR AND ATTITUDES		
Schemmann, Chappin and Herrmann, 2017	solution-oriented behaviour		financial attractiveness	Gruner and Homburg, 2000
Schemmann, Chappin and Herrmann, 2017	attention to other's idea		trustworthiness, credibility	LaBahn and Krapfel, 2000; Füller *et al.*, 2009
Morrison, Roberts and Midgley, 2004	early adoption mindset		personal level of interaction	Gruner and Homburg, 2000; Lettl, 2007
			closeness of relationship	Gruner and Homburg, 2000

Source: own compilation

The length of the sub-sections is decreasing because of the following reasons. Firstly, firms involve lead users mainly in the fuzzy front end of the NDP process; therefore, scholars discuss mainly this stage of the NDP. Secondly, in the case of incremental innovations, firms do not require additional expertise from users as they apply their own technical expertise in higher stages of the NDP. In the case of radical innovations, companies involve users only with advanced technological skills in the development stage of the NDP. The number of capable users in higher stages of the NPD is decreasing as the higher levels require additional personal characteristics and they are more challenging to fulfil.

4.4.1. Idea Generation Stage

Knowledge and Experience

Scholars (Lüthje, Herstatt and Von Hippel, 2005; Lettl, 2007a) emphasize the importance of the users' prior technical knowledge, experience and skills as these elements determine the type of idea and the solution the user will develop. Users utilize their own "local" (tacit) stock of need and solution knowledge to develop innovative ideas and products. This repertoire is in line with the statement of Shane (2000), which argues that the discovery of a certain innovation opportunity is driven by the user's prior education, knowledge and work experience. Lettl (2007) highlights the importance of in-depth professional knowledge and 'need knowledge' of medical surgeons as a crucial basis for innovative idea generation and solutions that meet specific needs.

This type of knowledge gained through experience, experimentation, and extensive learning is tacit; therefore, it is "sticky", very complex, poorly encoded and thus very hard and costly to transfer from users to manufacturers (Polanyi, 1958; von Hippel and Sonnack, 1999; Lüthje, 2004a; Lettl, 2007a; Faullant, Erich J Schwarz, *et al.*, 2012). Consequently, this may explain the reason why users develop radically new ideas instead of manufacturing firms that are more focused on incremental improvements (Lettl, 2007a). Schweisfurth (2017) compares internal and external lead users and found that employees who possess 'need knowledge' are able to take advantage of direct access to the organisation's knowledge to work out their solution and they are more creative than an employee who lacks 'need-knowledge'. The same author additionally states that creativity-enhancing knowledge schemas (e.g., solution knowledge) and creativity-hindering knowledge schemas provided by a company may contain knowledge that increases the resistance to change. The same study also highlights that internal user ideas are easier to realize, while external user ideas have maximum novelty, user value, and market potential.

Multiple studies find a positive effect of use-experience and product-related knowledge on the innovation activities of the users (Lüthje, 2004a; Füller, Jawecki and Mühlbacher, 2007; Schreier and Prügl, 2008a; Marchi, Giachetti and de Gennaro, 2011; Gürkan, 2014; Mahr, Lievens and Blazevic, 2014). Schweitzer, Gassmann and Rau (2014) emphasize that technically savvy users are more likely to generate technically feasible ideas, while technologically innovative customers tend to provide radical or new product ideas. According to LaBahn and Krapfel (2000), the technical innovativeness of customers increases the intention of firms to involve them in the early stages of the NPD process.

Motivation and Willingness

According to Füller *et al.* (2012), a certain level of interest and task motivation is important in the idea-generation phase to come up with new ideas, based on the evidence that creativity is driven by intrinsic motivation (Csikszentmihalyi, 1988). In contrast, Faullant, Erich J Schwarz*, et al.* (2012) found that intrinsic and extrinsic motivation does not significantly describe the traits of lead users. In the consumer context, Füller, Jawecki and Mühlbacher (2007) examined the proportion of motivation-driven factors and found that 20% of the innovations are "need-driven" and 80% are "excitement-driven". The "need-driven" innovation is triggered by the perception of needs not yet fulfilled by the existing products on the market, while the "excitement-driven" innovators develop new ideas because of enjoyment, fun and pleasure, and less due to the desired outcome. This study also claims that community members are willing to share their innovative ideas with manufacturing firms free of charge. Marchi, Giachetti and de Gennaro (2011) express that willingness to collaborate and strategic alignment with brand identity are crucial characteristics of the users' innovativeness.

In the industrial context, Gürkan (2014) found intrinsic motivation as the main characteristic of lead users. Lettl, Herstatt and Gemünden (2006) state that in terms of radical innovations in the medical domain, manufacturers are reluctant to invest in NPD, considering the design instabilities that trigger the users' entrepreneurial mindset to gain direct benefit from the tailored new technologies of their needs. The same authors emphasize that professional users experience difficulties in their daily work and they encounter the limits of conventional technologies, which motivate them to search for more workable solutions (motivation induced by problem). This strong intrinsic motivation supports creative activities (Csikszentmihalyi, 1988; Füller *et al.*, 2012) and enables innovations.

Creativity and Skills

Füller *et al.* (2012) examine the impact of customers' creativity components at different stages of the NPD process. They found that users in the idea-generation phase need to possess creativity-relevant processes, including extraordinary domain-relevant skills and an appropriate motivation level, heuristics, and work style to create creative ideas, while domain-specific skills have no impact on ideas. This finding was explained by the intention of companies being more interested to find and figure out a problem because they usually have strong abilities to develop and produce new products.

The research conducted by Kratzer and Lettl (2008) among children shows that "betweenness centrality" (i.e., the bridging link between different social groups in a network) and age have a significant effect on creativity. Children can create more and better ideas with increasing age and cognitive capacity. According to their study, the favourable network position of children stimulates individuals to utilize the information advantage and to become creative. This is consistent with the research conducted among young adults as lead users (Kratzer *et al.*, 2016).

In the industrial context and in the medical domain, Lettl (2007) states that high problem pressure is the key source of creative activities. A divergent thinking style is an ability to "think outside of the box" and not being restricted by functional fixedness (Faullant, Erich J Schwarz, *et al.*, 2012).

Close access to transdisciplinary know-how increases users' creative capacity (Lettl, 2007a). Schreier and Prügl (2008a) found that innate innovativeness explains creative achievements, including individuals who break "patterns of accepted modes of thought and actions" (Kirton, 1976, p. 623), and similarly, they "tend to take control in unstructured situations" (ibid) and are resistant to former standards and possess a risk-taking manner. The study also states that locus of control (LOC) (Rotter, 2006) is a personal characteristic and a key element of creativity (Exner and London, 1978). Moreover, they found that lead users possessing high internal LOC are likely to deal with new usage situations. They leave the solid terrain of the ordinary, usually commit to a difficult risky task and put effort into mastering improvements in existing products.

Behaviour and Attitude

Schemmann, Chappin and Herrmann (2017) investigated ideators' online behaviour and they found that their value lies in solution-oriented behaviour and paying attention to others' ideas. The solution-oriented behaviour is more related to suggesting improvements on existing goods than suggesting ideas. The ideators, who are curious and open to other ideators' ideas, are more likely to be successful. Lead users with early product adaption behaviour are a valuable source of new ideas and additionally, they can successfully fuel the market diffusion process (Morrison, Roberts and Midgley, 2004).

According to Füller *et al.* (2009), empowered customers are more innovative through IT tools for co-creation, they feel trust and are willing to put effort into making a valuable contribution. Such a tool enables less-skilled customers and lower-qualified users to participate in the virtual NPD task.

In the industrial context, Gruner and Homburg (2000) found that close customers and financially attractive customers yield a positive impact on the success of NPD, which relates to their market representation and reputation on the market. Additionally, they state that intensive customer interaction and close customers positively influence the product's success. In line with this statement, Lettl (2007) underlines the importance of personal face-to-face interactions with users to develop and understand the user's complex and tacit information to be transferred. Gruner and Homburg (2000) found that personal interaction can increase the new product success during the early and late stages of the NPD, while the concept generation stages yield no impact. Appropriate skills for interaction need to be developed in radical innovation projects with respect to the users and firms. Ref. (LaBahn and Krapfel, 2000a) claimed that in the collaboration process, firms require trustworthiness and credibility from customers otherwise they will ignore them.

4.4.2. Concept Generation Stage

Hoffman, Kopalle and Novak (2010) state that consumer innovativeness correlates positively with personality traits and processing abilities. Such customers, called "emergent nature customers", possess unique capabilities to envision or imagine how new product concepts might be developed. These unique personality traits and processing abilities support the product concept stage, enhance the ability to process information visually and verbally, and they are open to new experiences, reflection, thinking styles, and a high level of creativity and optimism. In contrast, Hamdi-Kidar *et al.* (2019) found that lead users and also average users outperform the "emergent nature customers".

Schweitzer *et al.* (2015) state that technologically reflective customers demonstrate benefits in the concept generation and refinement phase. Technologically reflective customers can think about the impact of a product on its user's society in general.

Füller *et al.* (2012) find that domain-specific skills (e.g., factual knowledge of the domain, familiarity, and technical skill) and creativity-relevant processes have a lower impact on concept generation in comparison with idea generation. The authors also highlighted that task motivation has no impact on concept development or on prototype development.

In the industrial context, only a few studies have been found that investigate users' characteristics in the concept development phase. Lettl (2007) defines critical lead user characteristics including imagination capabilities, openness to technologies outside of the certain domain, and close access to an interdisciplinary approach. They all inspire creative thinking to develop state-of-the-art technologies. The availability of resources for research, e.g., time, human resources, and funds, are important individual and contextual factors in this stage of the NPD. Users without a supportive environment and available resources exhibited lower efficiency. Characteristics elements, such as problem-induced motivation, openness, and prior knowledge, play a crucial role at this stage of new product development as well (Lettl, 2007a).

4.4.3. Prototype Development and Testing Stage

A limited number of studies have been found regarding the last stages of the NPD, i.e., prototype development, product development, and the testing stage.

In the consumer domain, Füller *et al.* (2012) state that at this level of the NPD, the creativity-relevant processes and task motivation have no impact on the contribution of users, while domain-specific skills play an enhanced role in the users' interest in experiencing and testing new products. Sadowski (2017) states that the willingness to experiment is crucial at this stage, which is aligned with the ideas of Lettl (2007) as well.

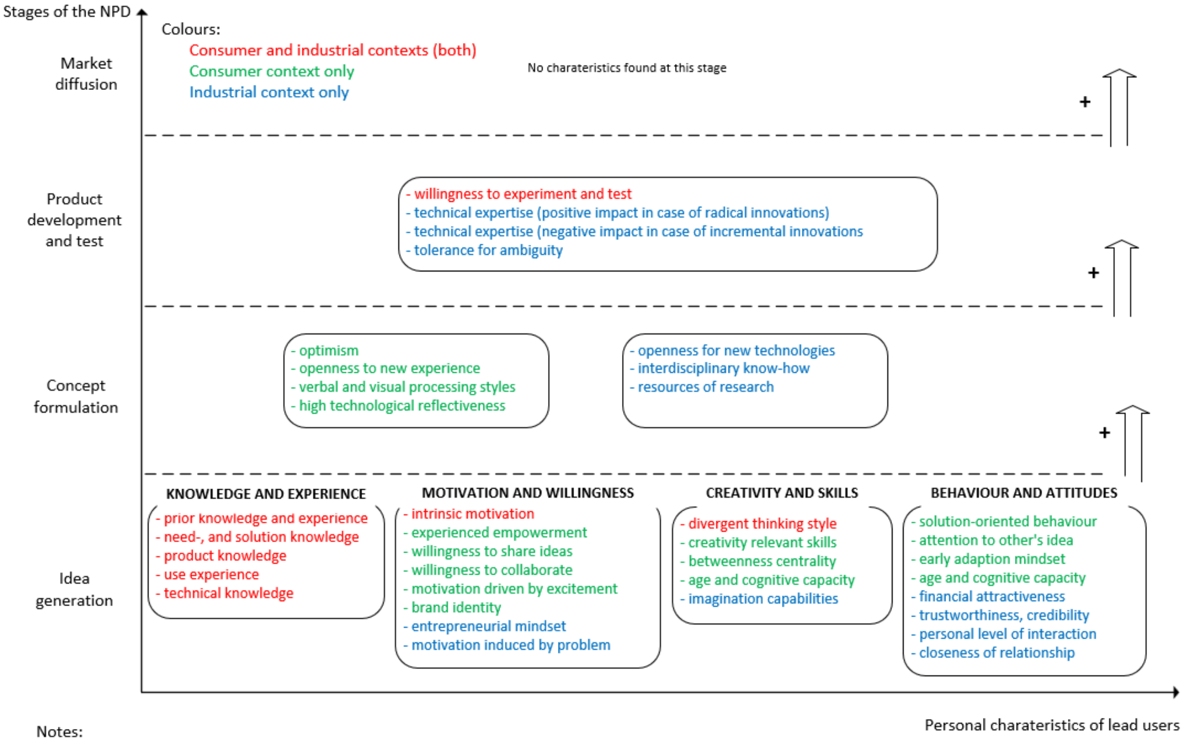
In the industrial context, Lettl (2007) realized that the characteristics of tolerance for ambiguity are essential to deal with uncertainty between the final output and the benefit of the product. The author emphasizes the importance of technological competencies, such as mechanics, electronics, and computer programming, in cases of radical innovations. In contrast with this finding, Gruner and Homburg (2000) concluded that there is a negative performance impact of technically attractive users related to their contribution to the development of mid-range (innovations between minor and radical changes) innovations. They argued that companies rely on their own technical expertise, and they shall not expect additional skills from users.

4.5. Discussion

Based on the above-presented systematic literature review, this paper has provided an overview of lead users' personal characteristics related to NPD in the case of co-creation. Altogether, 45 primary studies were found by performing the automatic and manual search processes, applying inclusion and exclusion criteria, and conducting a quality assessment. The selected studies have been organized into two categories, i.e., consumer and industrial contexts, as they provide the key research settings of the studies. The majority of the articles, 73% (33 studies), were related to the consumer context and 27% (12) were to the industrial context. To fulfil the quality and accuracy criteria and strengthen the researchers' confidence in the overall quality of the selected papers, the authors conducted a quality assessment process related to the primary studies. The assessment process resulted in 64% (29) high-quality papers, 16% (7) medium-quality papers and 20% (9) low-quality papers. To reduce the possibility of bias, the data extraction form has been defined (Appendix A) to record all information accurately that the authors obtained from the primary 45 studies.

To report the findings in a systematic way and provide an answer to the research question, we classified the NPD process into three stages, which are the following: 1. idea generation, 2. concept formulation, and 3. prototype and product development and test stages. We have found that most of the studies focus only on a fuzzy front end of the NPD process, and they discuss the personal characteristics of lead users only in connection with the idea generation stage. A limited number of studies have been found which discuss the characteristics in the later stages of NPD because fewer users are involved in the subsequent stages of the new product development process. The reason is that the number of capable users is decreasing as the higher levels require additional personal characteristics and they are more challenging to fulfil. We summarized the found personal characteristics elements in Figure 4.4.

Figure 4.4. Required personal characteristics of lead users in different stages of the NPD process.



Notes:
- Higher stages absorb skills from lower levels.
- Less lead users can be identified at the higher stages of the NPD as they require complex characteristics, which are rarely available (rare object).

Source: own compilation

We find significant differences in the consumer and industrial segments which shed light on the importance of context separation. This knowledge provides additional information for innovation managers to select the proper lead user for their co-creation process. The perspective of the market contexts provides complementary information and enables us to consider the required personal characteristics of lead users as a two-dimensional system: 1. personal characteristics in different stages of the NPD process and 2. personal characteristics in a dedicated market context. The differences are explained below and summarized in Table 4.8.

In the consumer segments, most of the lead users can be described as a hobbyist (Jeppesen and Frederiksen, 2006; Lettl, Herstatt and Gemünden, 2006; Schreier and Prügl, 2008a). Firms utilize online IT tools to involve "low-skilled users" without any face-to-face interaction (Jeppesen and Frederiksen, 2006; Füller *et al.*, 2009). The minority of lead users' motivation is "need-driven" and the majority is "excitement-driven" (Füller, Jawecki and Mühlbacher, 2007) and experiment-driven (Shah and Sonali, 2005; Füller, Jawecki and

Mühlbacher, 2007) or simply driven by the enjoyment of the activity (Lüthje, Herstatt and Von Hippel, 2005). The type of innovation refers to incremental innovation (Jeppesen and Frederiksen, 2006) improvements, smaller changes (Lüthje, 2004a; Trott, Duin and Hartmann, 2013) and can be characterized by low novelty (Morrison, Roberts and Von Hippel, 2000). Lead users can be identified in the early phase of the co-creation process (Füller, Jawecki and Mühlbacher, 2007). Community membership and strategic alignment with brand identity have a positive impact on the motivation to interact (Marchi, Giachetti and de Gennaro, 2011). Lead users in the consumer segment tend to earn free rewards. The innovation capabilities of lead users remain low, which corresponds to the required skills of firms in the consumer segment in the idea generation phase. According to (Scaringella, 2017), lead users in the consumer segments decide emotionally.

In the industrial segment, most of the lead users are professionals (Jeppesen and Frederiksen, 2006; Lettl, Herstatt and Gemünden, 2006). The co-creation process requires a high level of personal interaction, but its intensity varies in different stages of the NPD process (Mahr, Lievens and Blazevic, 2014). The motivation of lead users is triggered by needs and problems. Lead users in the industrial segments produce mostly radical innovations. The identification of lead users can happen in the later phase of the NDP process as lead users innovate during their everyday work (Lettl, 2007a). Firms apply no tools to involve lead users in the co-creation. The innovation capabilities of lead users are well-developed (Pulles, Veldman and Schiele, 2014). The decision base of lead users is mainly rational.

Table 4.8. Differences in the consumer and industrial segments.

	Consumer Context	**Industrial Context**
Type of Users:	hobbyist (Jeppesen and Frederiksen, 2006; Lettl, Herstatt and Gemünden, 2006; Schreier and Prügl, 2008a)	professionals (Jeppesen and Frederiksen, 2006; Lettl, Herstatt and Gemünden, 2006)
Interaction/ Participation	online user communities without face-to-face interaction (Jeppesen and Frederiksen, 2006); application of IT tools for "low-skilled users" to involve (Füller *et al.*, 2009)	high level of personal interaction (face-to-face) (Lettl, 2007a; Mahr, Lievens and Blazevic, 2014); the intensity of customer interaction varies in different stages of the NPD process
Motivation:	20% "need-driven" and 80% "excitement-driven" (Füller, Jawecki and Mühlbacher, 2007), enjoyment of activity (Lüthje, Herstatt and Von Hippel, 2005), experiment-driven (Shah, 2006; Füller, Jawecki and Mühlbacher, 2007)	induced by needs and problems (Lettl, 2007a)
Type of Innovation:	incremental (Jeppesen and Frederiksen, 2006)	radical innovation (Lettl, 2007a)

	improvements, smaller changes (Lüthje, 2004a); can be characterized by low novelty (Morrison, Roberts and Von Hippel, 2000) and lack of users' knowledge (Scaringella, 2017).	
Identification of Lead Users Status:	at the beginning of the NPD process (Füller, Jawecki and Mühlbacher, 2007)	in later phases of the NPD process (Lettl, 2007a)
Needed Tools:	online tools	no tools
Belonging to Community:	motivates greater involvement and willingness to interact (Marchi, Giachetti and de Gennaro, 2011)	community membership does not impact willingness to become inventive
Brand Identity/Loyalty	strategic alignment with brand identity (Marchi, Giachetti and de Gennaro, 2011)	-
Reward:	free	-
Innovation Capabilities:	low	well-developed (Lettl, 2007a; Pulles, Veldman and Schiele, 2014)
Decision Base:	emotional (Scaringella, 2017)	rational

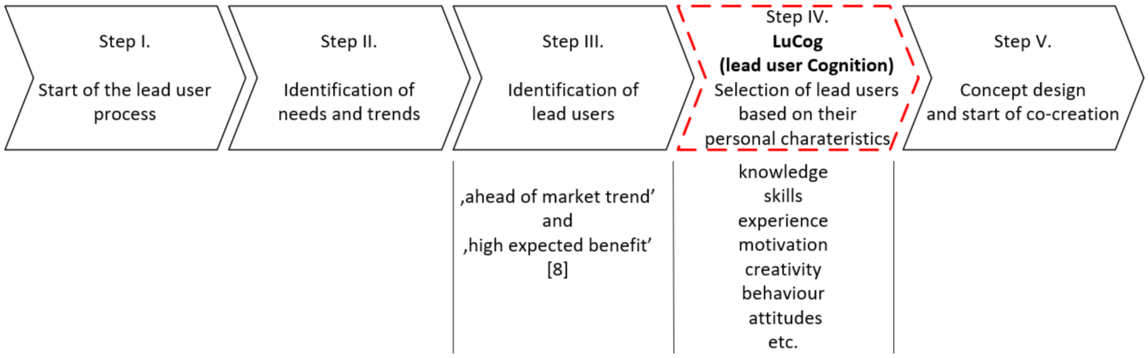
Source: own compilation

4.6. Contribution, Implications and Future Research

In conclusion, we state that the personal characteristics of lead users play a crucial role in the co-creation process, which varies in different stages of the NDP, separated into the consumer and industrial segments. The proper selection of lead users is essentially important as the quality of contribution highly influences the success of the open innovation process. This could result in a reduced time-to-market ratio and increased profitability.

Based on the results of the SLR and the key arguments, the authors made a contribution to the theory by extending the lead-user method with an additional step of "selection of lead users based on their personal characteristics". With this extension, we emphasize the relevancy and impact of lead users' personal characteristics on the entire co-creation process. The importance of the extension is confirmed by the identified 45 primary studies that strongly highlight the positive impact of proper lead users' personal characteristics on the success of open innovation. We formulated the outcomes of the study in the form of a partial theory named "Lead User Cognition" (LuCog) which is an additional stage in the lead-user method between the steps of "identification of lead users" and "concept design and the start of co-creation phases as Figure 4.5. shows. The name of the partial theory (LuCog) conveys the essence of the extension as it aims to express the relevance of the lead user cognition process of decision-makers during the lead user selection process.

Figure 4.5. The extended lead-user method.



Source: own compilation

The review also contributes to practice as managers can make a better selection of external contributors (lead users) during their open innovation process. The extended version of the lead-user method provides a crucial tool for decision-makers to select the right lead users for certain stages of the NPD process. The more accurate selection of lead users leads to higher innovation productivity and allows us to reduce development cost and time, shorten the time-to-market factor and help firms to realize a higher profit.

The study has some limitations as the users' characteristic elements have been investigated only on the individual level. Two characteristic elements, such as "ahead of market trend" and "high expected benefit", were eliminated from the investigation as the lead-user method contains it in step three (Figure 4.1.). Moreover, we have also omitted the big five personality traits, which were investigated by Stock, von Hippel and Gillert (2016).

Although the Lead User Theory and Method was created by Eric von Hippel in 1986, the authors decided to review studies published between the time frame of 2000 and 2020 for the following reasons. First, scholars started to reflect on the importance of the personal characteristics of lead users only after 2000. Second, the application of the snowballing approach during the study selection process by a manual scan of all references of the primary studies results in relevant studies which may not be covered by the automatic and manual searches.

The snowballing search offered an opportunity to take into consideration the synonyms of the word "characteristics", e.g., characteristic, attribute, skills, and abilities. We have included all studies that have used any of the synonyms of characteristics and fulfilled the substantial aims of the SLR.

Scholars have generally focused so far on some high-tech industries and consumer products, where lead users are attractive and therefore easy to recognize their activities. Little attention has been paid so far to the role of lead users' personal characteristics in hidden domains such as healthcare instruments and tools development or agriculture. Different market contexts require different characteristics which open new perspectives. Further research goals can be derived from the different considerations of our LuCog method. It can be interpreted as the cognition process of managers during their selection process in the fuzzy front end of the co-creation process and also can be understood as a cognition process of lead users by choosing the right firm to co-create. Both topics are neglected in the academic literature.

In sum, further research results in different contexts can lead to a better understanding of the selection criteria of lead users as well as those management techniques which could be applied in open innovation processes. New results facilitate the process wherein managers open their company boundaries in order to tap lead users' product-related ideas, knowledge, and experience. They can better exploit the advantage of open innovation and adjust open innovation dynamics to changing market conditions and customer needs.

Author Contributions: Conceptualization, B.V., A.G.R. and T.D. methodology, B.V., validation, B.V. and T.D., formal analysis, B.V.; investigation, B.V.; resources, B.V.; data curation, B.V.; writing—original draft preparation, B.V. and T.D.; writing—review and editing, T.D. and A.G.R.; visualization, B.V.; supervision, T.D. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: Details of the 45 primary studies selected are included in this paper.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A – Data Extraction Form

SID	References	Context	Key Findings	Method	Country	Type of Paper	Data Provider	Number of Samples (n)	Journal Name
S1	Abrell, Thomas, Matti Pihlajamaa, Laura Kanto, Jan Vom Brocke, and Falk Uebernickel. “The Role of Users and Customers in Digital Innovation: Insights from B2B Manufacturing Firms.” Information and Management 53 no. 3, (2016): 324–35. (Abrell *et al.*, 2016)	industrial (B2B manufacturing of marine vehicles, power plants)	The paper differentiates customer and user knowledge. End-users use the product but do not make a purchasing decision. The customers buy the products but do not use them directly. User knowledge is often tacit and sets long-term development goals. Customers can provide explicit knowledge to reach short-term needs.	qualitative (holistic case study)	-	Journal	ScienceDirect	30	Information and Management
S2	Bilgram, Volker, Alexander Brem, and Kai Ingo Voigt. “User-Centric Innovations in New Product Development - Systematic Identification of Lead Users Harnessing Interactive and Collaborative Online-Tools.” *International Journal of Innovation Management* 12, no.3 (2008): 419–58. (Bilgram, Brem and Voigt, 2008)	consumer	The paper reveals some characteristics of lead users as a crucial factor in online identification of lead users: being ahead of trend, high expected benefit, user expertise and motivation, extreme user needs, opinion leadership and online commitment.	qualitative (review)	-	Journal	ScienceDirect	-	International Journal of Innovation Management
S3	Brem, Alexander, and Volker Bilgram. “The Search for Innovative Partners in Co-Creation: Identifying Lead Users in Social Media through Netnography and Crowdsourcing.” Journal of Engineering and Technology Management - JET-M 37 (2015): 40–51. (Brem and Bilgram, 2015)	consumer	The study states that participation in online communities can be a new indicator and potentially effective criteria for assessing lead user potential which can be effectively discovered through social media by netnography and crowdsourcing.	qualitative (case study)	-	Journal	ScienceDirect	24	Journal of Engineering and Technology Management
S4	Enkel, Ellen, Javier Perez-Freije, and Oliver Gassmann. “Minimizing Market Risks Through Customer Integration in New Product Development: Learning from Bad Practice.” *Creativity and Innovation Management* 14, no. 4 (2005): 425–37. (Enkel, Perez-Freije and Gassmann, 2005)	industrial (machine engineering)	The study describes the case when a company follows all the steps that lead user theory recommends but the project fails. The reason is that companies may not understand when and how to use the lead user method to reduce the risk of innovation and market. The selection and customer integration need a skilled person. The integration shall involve steps such as 1. finding customers with the right knowledge, 2. selecting the right customer category, 3. customer integration in the early phase, and 4. keeping high the project team motivation for integrating customers.	qualitative (case study)	Europe and Asia	Journal	Wiley Online Library	50	Creativity and Innovation Management

S5	Faullant, Rita, Erich J. Schwarz, Ines Krajger, and Robert J. Breitenecker. “Towards a Comprehensive Understanding of Lead Userness: The Search for Individual Creativity.” *Creativity and Innovation Management* 21, no. 1 (2012): 76–92. (Faullant, Erich J Schwarz, *et al.*, 2012)	consumer (kitchen appliances)	The study determines characteristics which are related to lead userness: 1. individual creativity and personality play an important role in the deterministic of lead userness; 2. domain-relevant skills (product-related knowledge and use-experience) and creativity-relevant skills (divergent thinking style) are related to lead userness; 3. intrinsic motivation. Individual creativity can be explained by personality-related characteristics.	qualitative (empirical study)	Germany	Journal	Wiley Online Library	146	Creativity and Innovation Management
S6	Franke, Nikolaus, Eric von Hippel, and Martin Schreier. “Finding Commercially Attractive User Innovations: A Test of Lead-User Theory*.” *Journal of Product Innovation Management* 23, no. 4 (2006): 301–15. (Franke, von Hippel and Schreirer, 2006)	consumer (kite surfing)	The study confirms that the "high expected benefit" dimension leads to higher innovation likelihood and the "ahead of trend" dimension predicts innovation likelihood and commercial attractiveness of the innovation developed by the user. Technical expertise and community-based resources are recommended as search criteria next to the two lead-user components.	quantitative	Europe	Journal	Wiley Online Library	456	Product Innovation Management
S7	Fredberg, Tobias, and Frank T. Piller. “The Paradox of Tie Strength in Customer Relationships for Innovation: A Longitudinal Case Study in the Sports Industry.” R&D Management 41, no. 5 (2011): 470–84. (Fredberg and Piller, 2011)	consumer (sportswear)	The paper finds that active and strong ties between customers and the company support significant innovation. This opportunity can lead to better innovation only when a firm builds proper co-creation capabilities.	qualitative (case study)	Germany	Journal	Wiley Online Library	-	R&D Management
S8	Füller, Johann. “Refining Virtual Co-Creation from a Consumer Perspective.” *California Management Review* 52 no. 2 (2010): 98–122. (Füller, 2010)	consumer	The researchers identify four different kinds of users engaging in co-creation: intrinsically interested, curiosity-driven, need-driven, reward oriented.	qualitative (empirical study)	-	Journal	Google Scholar		California Management Review
S9	Füller, Johann, Katja Hutter, and Rita Faullant. “Why Co-Creation Experience Matters? Creative Experience and Its Impact on the Quantity and Quality of Creative Contributions.” *R&D Management* 41, no. 3 (2011): 259–73. (Füller, Hutter and Faullant, 2011)	consumer (Swarowsky design competition)	The study highlights that the former co-creation experience has a significant impact on the quality of submitted designs.	qualitative (case study)	global	Journal	Google Scholar	298	R&D Management

S10	Füller, Johann, Gregor Jawecki, Hans Muhlbacher, Johann Fuller, Gregor Jawecki, and Hans Muhlbacher. "Innovation Creation by Online Basketball Communities." *Journal of Business Research* 60, no. 1 (2007): 60–71. (Füller, Jawecki and Mühlbacher, 2007)	consumer (basketball shoes)	The study state that only very knowledgeable members of the community are innovative and modify existing or create new basketball shoes. They are willing to share their ideas with sports equipment manufacturer companies. The success of virtual integration depends on the communities innovation potential and the consumer's willingness to participate. These innovators are 20% "need-driven" and 80% "excitement-driven".	qualitative (netnography)	Germany	Journal	ScienceDirect		Journal of Business Research
S11	Füller, Johann, Kurt Matzler, Katja Hutter, and Julia Hautz. "Consumers' Creative Talent: Which Characteristics Qualify Consumers for Open Innovation Projects? An Exploration of Asymmetrical Effects." *Creativity and Innovation Management* 21, no. 3 (2012): 247–62. (Füller *et al.*, 2012)	consumer (virtual NPD project)	The research results that the impact is asymmetric between the consumer's ability to generate ideas and to develop new products. The threshold levels of domain-specific skills, creativity-relevant processes and task motivation are investigated at different stages of product development as idea generation, evaluation of product concepts and interest, testing new products and also interest in co-creation.	quantitative	n/a	Journal	Wiley Online Library	825	Creativity and Innovation Management
S12	Füller, Johann, Hans Mühlbacher, Kurt Matzler, and Gregor Jawecki. "Consumer Empowerment through Internet-Based Co-Creation." *Journal of Management Information Systems* 26, no. 3 (2009): 71–102. (Füller *et al.*, 2009)	consumer (NPD project from ten different fields)	The paper presents that Internet-based tool that contributes to customers' empowerment in virtual new product co-creation activities. Lead users have a higher need to express their knowledge and articulate their needs. The co-creation tools make stronger feelings of empowerment among customers.	quantitative	-	Journal	Wiley Online Library	727	Journal of Management Information Systems
S13	Globocnik, Dietfried, and Rita Faullant. "Do Lead Users Cooperate with Manufacturers in Innovation? Investigating the Missing Link between Lead Userness and Cooperation Initiation with Manufacturers." *Technovation* 100 (2021) (Globocnik and Faullant, 2021a)	industrial (health care)	The study investigates the link between user and manufacturer interaction and finds that lead users not only help a firm to understand the problem but also they can provide a solution for them.	quantitative	Germany and UK	Journal	ScienceDirect	243/146	Technovation
S14	Goyal, Sandeep, Manju Ahuja, and Atreyi Kankanhalli. "Does the Source of External Knowledge Matter? Examining the Role of Customer Co-Creation and Partner Sourcing in Knowledge Creation and Innovation." *Information and Management* 57, no. 6 (2020) (Goyal, Ahuja and Kankanhalli, 2020)	consumer (financial / IT)	The paper states that different forms of external knowledge contribute differentially to knowledge creation.	quantitative	USA / Singapore	Journal	ScienceDirect	399	Information and Management

S15	Gruner, Kjell E., and Christian Homburg. 2000. "Does Customer Interaction Enhance New Product Success?" *Journal of Business Research* 49, no. 1 (2000): 1–14. (Gruner and Homburg, 2000a)	industrial (machinery industry)	The paper states that customer interaction has a positive impact on product success during the early and late stages of the NPD process while interaction in the middle stages has no performance impact. Technically attractive customers have a negative impact on NPD explained by different effects. Financially attractive customers, lead users and close customers have a positive impact as attractive partners in NPD.	quantitative	Germany	Journal	ScienceDirect	310	Journal of Business Research
S16	Güney, Çetin and Cetin Gürkan, Güney. "Identification of Lead User Characteristics: The Case of Surgeons in Turkey." *European Journal of Business and Management*. 6. (2014). (Gürkan, 2014)	industrial (health care)	The paper states that the high level of expected benefit, the frequent use of information and intrinsic motivation show significant differences between non-lead users and lead users. The research was performed in medical surgery in Turkey.	quantitative	-	Journal	Google Scholar		European Journal of Business and Management
S17	Hamdi-Kidar, Linda, Peter Keinz, Emmanuelle Le Nagard, and Eric Vernette. "Comparing Lead Users to Emergent-Nature Consumers as Sources of Innovation at Early Stages of New Product Development." *Journal of Product Innovation Management* 36, no. 5 (2019): 616-631. (Hamdi-Kidar *et al.*, 2019)	consumer (game of chance sector)	The article critically reflects the concept of Emergent-Nature Consumers (ENC) (Hoffman et al., 2010). The research states that the lead users outperform ENC and remain a primary source of innovations.	quantitative	French	Journal	Wiley Online Library	53	Product Innovation Management
S18	Hoffman, Donna L., Praveen K. Kopalle, and Thomas P. Novak. "The 'Right' Consumers for Better Concepts: Identifying Consumers High in Emergent Nature to Develop New Product Concepts." *Journal of Marketing Research* 47, no. 5 (2010): 854–65. (Hoffman, Kopalle and Novak, 2010)	consumer (home SmartBox)	The paper states that product concepts developed by customers with high emergent nature (openness to new experiences, reflection, verbal and visual processing styles, experimental and rational thinking style, creativity and optimism) ultimately lead to greater sales compared to products that are developed by other types of customers.	quantitative	global	Journal	JSTOR	1124	Journal of Marketing Research
S19	Jeppesen, Lars Bo, and Lars Frederiksen. 2006. "Why Do Users Contribute to Firm-Hosted User Communities? The Case of Computer-Controlled Music Instruments." Organization Science. 17 (2006): 45-63. (Jeppesen and Frederiksen, 2006)	consumer (musical instruments)	The research investigates the key personal attributes of customers which responsible for innovations. Innovative users are hobbyists (there is a willingness to share innovations) or responsive to "firm recognition" to undertake innovation. It has been also found that innovative users are	multiple methods	-	Journal	Google Scholar	345	Organization Science

			like to be lead users which positively impacts the quality of innovation.						
S20	Kratzer, Jan, and Christopher Lettl. 2008. “A Social Network Perspective of Lead Users and Creativity: An Empirical Study among Children.” *Creativity and Innovation Management* 17, no. 1 (2008): 26–36. (Kratzer and Lettl, 2008)	consumer (school groups of children)	The study found that users with betweenness centrality (boundary-spanning position) are able to create highly novel ideas in the idea generation phase. The betweenness centrality also determines creativity by minimizing communication barriers. A positive correlation has been found between being creative and lead user.	quantitative	Netherlands	Journal	Wiley Online Library	45	Creativity and Innovation Management
S21	Kratzer, Jan, Christopher Lettl, Nikolaus Franke, and Peter A. Gloor. 2016. “The Social Network Position of Lead Users.” *Journal of Product Innovation Management* 33, no. 2 (2016): 201–16. (Kratzer *et al.*, 2016)	consumer	Lead users are positioned as bridges between different social groups which can be mapped by modern online mining tools quickly and low at cost and help companies to increase the effectiveness and efficiency of lead user identification.	quantitative	Netherlands	Journal	Wiley Online Library	267/3118/50	Product Innovation Management
S22	LaBahn, Douglas W., and Robert Krapfel. “Early Supplier Involvement in Customer New Product Development: A Contingency Model of Component Supplier Intentions.” *Journal of Business Research* 47, no. 3 (2000): 173–90. (LaBahn and Krapfel, 2000a)	industrial (OEM manufacturer)	The paper found that customer promise, interdependence technological innovativeness and supplier technical capability positively influence the intention of early supplier involvement in the NPD process.	quantitative	USA	Journal	ScienceDirect	422	Journal of Business Research
S23	Lettl, Christopher. “User Involvement Competence for Radical Innovation.” *Journal of Engineering and Technology Management* - JET-M 24, no, 1–2 (2007): 53–75. (Lettl, 2007a)	industrial (health care)	The study investigates users' characteristics at different stages of product development in the field of medical technology in case of radical innovations.	qualitative (case study)	-	Journal	ScienceDirect	45	Journal of Engineering and Technology Management
S24	Lettl, Christopher, Cornelius Herstatt, and Hans Georg Gemuenden. “Users’ Contributions to Radical Innovation: Evidence from Four Cases in the Field of Medical Equipment Technology.” *R and D Management* 36, no. 3 (2006): 251-272. (Lettl, Herstatt and Gemünden, 2006)	industrial (medical)	The study investigates the characteristics of capable users at different levels of their contribution to radical innovations in the field of medical equipment technology. They have high motivation to search for new solutions, own a diverse set of competencies, are embedded in a	qualitative (case study)	-	Journal	Wiley Online Library	36	R&D Management

			supportive environment, and play an entrepreneurial role.						
S25	Lilien, Gary L., Pamela D. Morrison, Kathleen Searls, Mary Sonnack, and Eric Von Hippel. “Performance Assessment of the Lead User Idea-Generation Process for New Product Development.” Management Science 48, no. 8 (2002): 1042–59. (Lilien *et al.*, 2002)	industrial (3M)	The paper compares the lead user (LU) idea generation process with conventional methods and finds that the ideas generated by the LU process have a positive impact on the sales revenue, have a significantly higher novelty and are more original compared with traditional methods.	quantitative	-	Journal	Google Scholar	47	Management Science
S26	Lüthje, Christian. “Characteristics of Innovating Users in a Consumer Goods Field: An Empirical Study of Sport-Related Product Consumers.” *Technovation* 24, no. 9 (2004): 683–95. (Lüthje, 2004a)	consumer (outdoor sport products)	The paper states that the motivation of users to innovate is driven by their specific not fulfilled needs and by the realised discrepancy between the experienced and expected performance of the products. Approximately 9% of the sample users-built prototypes or marketable products and do it without contacting a firm to transfer their ideas, concept or prototypes.	quantitative	Germany	Journal	ScienceDirect	153	Technovation
S27	Lüthje, Christian, Cornelius Herstatt, and Eric Von Hippel. “User-Innovators and ‘Local’ Information: The Case of Mountain Biking.” *Research Policy* 34, no. 6 (2005): 951–65. (Lüthje, Herstatt and Von Hippel, 2005)	consumer (mountain bikes)	The study shows that a user's personal patterns of product usage ("local" information") highly influence the functionality of innovative ideas. The type of solution is determined by the technical knowledge and skills of the user. It offers that a fundamentally different approach to lead user identification might be possible when firms identify lead users with a specific type of needs (safety mountain bikes shall be developed with bikers who have a high need for safety).	qualitative (empirical study)	North America	Journal	Google Scholar	287	Research Policy
S28	Mahr, Dominik, Annouk Lievens, and Vera Blazevic. “The Value of Customer Cocreated Knowledge during the Innovation Process.” *Journal of Product Innovation Management* 31, no. 3 (2014): 599–615. (Mahr, Lievens and Blazevic, 2014)	industrial (various domains)	The paper states that the customers' knowledge and its novelty, the customer-firm closeness and the type of communication channels are impact factors of the success of customers' co-creation initiatives.	quantitative	Europe	Journal	Wiley Online Library	126	Product Innovation Management

S29	Marchi, Gianluca, Claudio Giachetti, and Pamela De Gennaro. "Extending Lead-User Theory to Online Brand Communities: The Case of the Community Ducati." *Technovation* 31, no. 8 (2011): 350–61. (Marchi, Giachetti and de Gennaro, 2011)	consumer (motorbike)	The study states that willingness to collaborate has a high impact, while product knowledge and strategic alignment with the brand identity have moderated effects on innovativeness in online brand communities.	quantitative	global	Journal	ScienceDirect	572	Technovation
S30	Morrison, Pamela D., John H. Roberts, David F. Midgley, Pamela D. Morrison, John H. Roberts, and David F. Midgley. "The Nature of Lead Users and Measurement of Leading Edge Status." *Research Policy* 33, no. 2 (2004): 351–62. (Morrison, Roberts and Midgley, 2004)	consumer (libraries)	The study highlight the values of lead users as early adopters, sources of new ideas, research potential and the role of fuelling the process of diffusion.	quantitative	Australia	Journal	ScienceDirect	432	Research Policy
S31	Morrison, Pamela D., John H. Roberts, and Eric Von Hippel. "Determinants of User Innovation and Innovation Sharing in a Local Market." *Management Science* 46, no. 12 (2000): 1513–27. (Morrison, Roberts and Von Hippel, 2000)	consumer (OPAC library information systems)	The study determines the characteristics of users who modify the system and share information about it. Innovating users are more likely to share their innovations with others.	quantitative	Australia	Journal	JSTOR	122	Management Science
S32	Piller, Frank & Walcher, Dominik. (2006). Toolkits for Idea Competitions: A Novel Method to Integrate Users in New Product Development. R&D Management. 36. (2006):307-318. (Piller and Walcher, 2006)	consumer (sport goods)	The article introduces a toolkit for idea competitions (TIC) to access users' innovative ideas and solutions and which encourages users to participate in the open innovation process and increase the quality of their submissions.	quantitative	Germany	Journal	Wiley Online Library	82	R&D Management
S33	Sadowski, Bert M. "Advanced Users and the Adoption of High Speed Broadband: Results of a Living Lab Study in the Netherlands." *Technological Forecasting and Social Change* 115, (2017): 1–14. (Sadowski, 2017)	consumer (high-speed broadband network)	The paper examines advanced users (lead users) by their characteristics, adoption behaviour and contribution to innovation.	quantitative	Netherlands	Journal	ScienceDirect	673	Technological Forecasting & Social Change
S34	*Sandmeier, Patricia, Pamela D. Morrison and O. Gassmann. "Integrating Customers in Product Innovation: Lessons from Industrial Development Contractors and In-House Contractors in Rapidly Changing Customer*	consumer (various)	The study compares the product innovation practices of two in-house developers (HILTI, Buechi) and two development contractors (IDEO, Tribecraft). It states that customer contribution is high for in-house	qualitative	Northern Europe	Journal	Wiley Online Library	-	Creativity and Innovation Management

	Markets." ERN: Innovation (Topic) *(2010): n. pag.* (Sandmeier, Morrison and Gassmann, 2010)		developers while it remains at a low level in the case of development contractors.						
S35	Scaringella, Laurent. (2017). "Involvement of "Ostensible Customers" in really new innovation: Failure of a start-up." *Journal of Engineering and Technology Management*, 43, (2017): 1–18. (Scaringella, 2017)	industrial development of PCB - (printed circuit board) quality tester	The study examines the process of product failure. Ostensible customers seem to offer benefits (motivation to solve problems, suggestions for improvements, experience sharing), but their value misleads due to a lack of knowledge, vaguely expressed wants and no real intent to purchase.	qualitative	French	Journal	ScienceDirect	19	Journal of Engineering and Technology Management
S36	Schemmann, Brita, Maryse M.H. Chappin, and Andrea M. Herrmann. "The Right Kind of People: Characteristics of Successful Ideators' Online Behaviour." *Creativity and Innovation Management* 26, no. 3 (2017): 277–90. (Schemmann, Chappin and Herrmann, 2017)	consumer (digital services)	The research states that ideators with solution-oriented behaviour (idea + solution) and positive attention to other ideators' ideas are likely to suggest ideas which can be implemented.	qualitative	Germany	Journal	Wiley Online Library	48	Creativity and Innovation Management
S37	Schreier, Martin, and Reinhard Prügl. "Extending Lead-User Theory: Antecedents and Consequences of Consumers' Lead Userness." *Journal of Product Innovation Management* 25, no. 4 (2008): 331–46. (Schreier and Prügl, 2008a)	consumer (extreme consumer sport fields)	The study extends the lead user theory with field-related variables (consumer knowledge, use experience, locus of control and innovativeness) as antecedents and adaptive behaviour as consequences. All observed variables support the characteristics of lead userness.	quantitative	global	Journal	Wiley Online Library	129/193/139	Product Innovation Management
S38	Schreier, Martin, Oberhauser, Stefan, Prügl, Reinhard. „Lead Users and the Adoption and Diffusion of New Products: Insights from Two Extreme Sports Communities". Marketing Letters. 18. (2007):15-30. (Schreier, Oberhauser and Prügl, 2007)	consumer (kite surfing, tech diving)	The study finds that lead users have high domain-specific innovativeness, perceive new technologies as less complex and therefore adopt new products early. Lead users have stronger opinion leadership and lower opinion-seeking characteristics.	qualitative (case study)	-	Journal	Google Scholar	139/143/193	Marketing Letters
S39	Schuhmacher, Monika & Kuester, Sabine. Identification of Lead User Characteristics Driving the Quality of Service Innovation Ideas. Creativity and Innovation Management. 21, no. 4 (2012): 427–442. (Schuhmacher and Kuester, 2012)	consumer (online services of soccer clubs)	The study investigates the context of new service development. It has been found that ahead of trend, expertise, consumer knowledge, and extrinsic motivation have a negative impact while dissatisfaction and intrinsic motivation have a positive impact on idea quality. The research states that the	quantitative	-	Journal	Wiley Online Library	120	Creativity and Innovation Management

			characteristics of lead users do not directly create creative output.						
S40	Schuurman, D., D. Mahr and L. Marez. "User characteristics for customer involvement in innovation processes : deconstructing the Lead User-concept." *ISPIM XXII Proceedings* (2011). (Schuurman, Mahr and De Marez, 2011)	consumer (various)	The study describes six user types based on five dimensions and proposes a guideline for the optimal integration of users.	qualitative	-	Conference proceedings	Google Scholar	-	ISPIM 22nd conference: Sustainability in innovation: innovation management challenges
S41	Schweisfurth, Tim G. 2017. "Comparing Internal and External Lead Users as Sources of Innovation." *Research Policy* 46 no. 1 (2017): 238–48. (Schweisfurth, 2017)	consumer (home appliance)	The study states that external user ideas have maximum novelty, user value, and market potential, while internal user ideas are more easily realizable compared to ordinary users.	quantitative	Germany	Journal	ScienceDirect	864/239	Research Policy
S42	Schweisfurth, T. G., & Raasch, C. (2015). Embedded lead users—The benefits of employing users for corporate innovation. Research Policy, 44(1), 168–180. (Schweisfurth and Raasch, 2015)	consumer (mountain engineering industry)	The study test and support the hypothesis that embedded lead users (employees who are lead users of their employing firm's product or services) foster innovation at work.	quantitative	Germany / Switzerland / Italy	Journal	ScienceDirect	149	Research Policy
S43	Schweitzer, Fiona, Oliver Gassmann, and Christiane Rau. 2014. "Lessons from Ideation: Where Does User Involvement Lead Us?" *Creativity and Innovation Management* 23, no. 2 (2014): 155–167. (Schweitzer, Gassmann and Rau, 2014)	consumer (smart home)	The study state that users with high technical skills lead to technically feasible ideas. Trend-aware and technically innovative users produce ideas of greater originality while ethically reflective users have ideas with a positive impact on society.	quantitative	-	Journal	Wiley Online Library	93	Creativity and Innovation Management
S44	Schweitzer, Fiona, Christiane Rau, Oliver Gassmann, and Ellis Hende. "Technologically Reflective Individuals as Enablers of Social Innovation*." *Journal of Product Innovation Management* 32, no. 6 (2015): 847–60. (Schweitzer *et al.*, 2015)	consumer (health monitoring system)	The paper systematically develops a multi-item scale to measure the level of technological reflectiveness (TR) of an individual. External sources with high TR scores can contribute to the early stages of the innovation process.	quantitative	-	Journal (PIM)	Wiley Online Library	-	Product Innovation Management

S45	Shane, Scott. “Prior Knowledge and the Discovery of Entrepreneurial Opportunities.” *Organization Science* 11, no. 4 (2000): 448–69. (Shane, 2000)	industrial (3D printer)	The study states that individuals can discover opportunities through recognition rather than search. Individuals with prior knowledge developed through education and work experience will more likely to discover innovation opportunities than people without prior knowledge.	qualitative (case study)	USA	Journal	Google Scholar	22	Organization Science

Source: own compilation

5. The Impact of Lead Users' Characteristics on the Various Stages of the NPD Process: The Case of Medical Device Innovations (second paper)

5.1. Abstract

Involving the right users in the NPD process is particularly challenging, as the contribution of individuals varies strongly. While the Lead User Method sets two criteria to identify lead users, it does not consider the personal characteristics of the external contributors that are required to achieve success in the lead user involved NPD. In the research, we identified six personal characteristics of lead users and their impact on the success of the NPD process as well as on the technical and market success of a new product. We have come to the following conclusions: 1. Lead users must be involved in the whole NPD process irrespective of the complexity of the new product. 2. Each characteristic of lead users differently impacts the various stages of the NPD process. Based on the research findings, we advanced the Lead User Method by extending it with an additional step of lead user selection and also linked the identified characteristics to the general attributes of lead users as "ahead of market trends" and "high expected benefit". The study reveals managerial implications by recommending signals for practices that facilitate the selection process of proper lead users in the fuzzy front end of the co-creation reducing the uncertainty, cost, and time of the NPD.

Keywords: lead user selection, personal characteristics, new product development, co-created NPD, medical device innovations

5.2. Introduction

Successfully innovating firms involve lead users in their new product development (NPD) process as these "leading-edge users" (von Hippel, 1986) are an important source of breakthrough and commercially attractive innovations (Baldwin et al., 2006; Fleming, 2007; Lettl et al., 2006; Lilien et al., 2002). According to Baldwin & von Hippel (2009), a large number of users (10 per cent to 40 per cent) modify or develop products by themselves including different types of industrial and consumer products (Herstatt & von Hippel, 1992; Lettl, 2007; Lüthje, 2004; Lüthje et al., 2005; Morrison et al., 2000; Urban & von Hippel, 1988). Lead users aim to collaborate with firms to carry out innovation together, especially if a product is complex, and the development requires special knowledge, tools and the existence of various standards (Globocnik & Faullant, 2021). Thus, lead users become the central and essential part of the whole NPD process (Cooper, 2001; O'Hern & Rindfleisch, 2010), including idea generation, concept design, product development, prototyping, market diffusion and post-launch activities (Hoyer et al., 2010).

Involving the right users into the NPD process is particularly challenging as the contribution of individuals strongly varies (Füller et al., 2012), and the personal characteristics of users significantly differ (Lettl, 2007). The human factor plays a crucial role because the synergy in innovation "can only be achieved if the right number of the right people is prepared to collaborate with each other" (Boer et al., 2006, p. 9). Abrell et al. (2018, p. 9) emphasize the importance of "selecting the right user profiles, which helps developers to set priorities and design with the most important groups of users in mind".

The question emerges: what personal characteristics of lead users shall be taken into consideration by NPD managers to select the appropriate lead users? Studies attempt to answer this question and shed light on a firm's competence to "involve the 'right users' at the 'right time' in the 'right form'" (Lettl, 2007) and investigate the users' characteristics for radical innovations (Lettl et al., 2006). Although the lead user method sets two general characteristics of lead users as "ahead of market trend" and "high expected benefit" only for the idea generation phase of the NPD, it does not consider the personal characteristics of individuals related to the whole NPD process. Consequently, the study aims to fill this research gap. Therefore, we present some novel insights into the matter based on the new European Union regulatory framework for medical device manufacturers (in effect since 2017), referred to as Medical Device Regulations, which set more rigorous requirements related to the whole NPD process and the involved participants compared to the previous regulation (European, Parliament, 2017).

The investigated research problem is relevant for NPD managers as they need to select appropriate lead users at the fuzzy front end of their co-created NPD process. Even though the lead user method contains the step of "identification of lead users", it does not mean that the identified lead users are suitable for a co-created NPD, especially with regard to their personal characteristics. Furthermore, NPD managers must ensure effective collaboration between internal employees (engineers, product owners etc.) and external contributors (lead users). In order to resolve this conflict, the research applies the Lead User Cognition method (Venesz et al., 2022), which refers to the cognition process of decision-makers during the selection of lead users by considering their personal characteristics. The method is embedded into the original lead user method by extending it with an additional step.

While the lead user method is generally applicable, the Lead User Cognition method requires a specific context for the generalisation and interpretation of the results. In order to improve our understanding of the impact of lead users' personal characteristics, the level of their involvement in the co-created NPD process, and their relation to the original lead user concept, we formulated the following research questions:

> RQ2: How comprehensively does a lead user need to be involved in the co-created NPD process?
>
> RQ3: How do the different personal characteristics of lead users impact the success of the NPD?
>
> RQ4: How can the identified personal elements be linked to the general characteristics of lead users as "ahead of market trend" and "high expected benefit"?

The results of our study contribute to the theory by elaborating the lead user method and proposing advancement for the lead users' identification and selection processes. Our main findings indicate that 1. the same lead users must be involved in the NPD; 2. their participation shall cover each stage of the new product development process, 3. the different stages of the NPD require different characteristics in order to achieve the success of the co-created new product development.

The research results also contribute to practice by providing six essential characteristic features of lead users that have a positive impact on the success of the NPD process. The identified elements are linked to the general characteristics of lead users by extending and refining the original lead user method. The study reveals managerial implications by proposing practices that facilitate the selection process of lead users in the fuzzy front end of the NPD. The paper also offers helpful insights for lead users in order to gain a better understanding of the selection processes of firms and perform a self-assessment about their appropriateness for the co-created NPD before turning to companies with their innovative idea.

The study is organised as follows: Chapter 2 reviews the theoretical background and develops the propositions. Chapter 3 describes the research method. Chapter 4 presents the findings discussed later in Chapter 5. The final section contains the theoretical, practical and managerial contributions, limitations, and further research proposals.

5.3. Background

In the research, we applied abductive reasoning through an iterative process between theory and practice which co-evolved our initial propositions and conceptual framework (Dubois et al., 2002). In the first step, we reviewed the academic literature about the personal characteristics of lead users and set our initial propositions.

Personal Characteristics of Lead Users

The personal characteristics of lead users have become an important focus of attention in research. Investigations mainly refer to the domain-related knowledge and experience (need knowledge) of users as these elements determine the type of idea and the solution users will develop (Lettl, 2007; Lüthje et al., 2005; Schreier & Prügl, 2008). The accumulated knowledge gained through long years of experience, experimentation, and extensive learning (Faullant et al., 2012; Lettl, 2007; Lüthje, 2004; Polanyi, 1958) enables users to create breakthrough ideas (Cooper & Kleinschmidt, 2007; Ernst, 2002; Hoban, 1998). Such lead users are able to make sense of innovation-related information (Cohen & Levinthal, 1990; Lüthje & Herstatt, 2004) and develop a solution to their needs. These individuals are recognised as experts in their domains (Faullant et al., 2012; von Hippel, 1986). According to the "Novice to Expert" model (Dreyfus, 2004; Dreyfus & Dreyfus, 1980), experts possess tacit knowledge, intuitive decisions, the ability to deal with complexity, see the overall big picture, think out of the box and break rules. We assume that lead users with an expert level of domain-related knowledge also contribute to the success of the NDP process in the context of medical device innovations and therefore, we formulate the following proposition:

Proposition 1: Expert level of domain-related knowledge of lead users positively influence the success of an NPD with lead user involved NPD.

Lead users reassemble and combine their prior knowledge to evaluate the best-fitting solution for their needs (von Hippel, 2005). The intensive utilization of both professional and technical knowledge and experience (solution knowledge) leads to innovative solutions, like the first device for gas chromatography (Riggs et al., 1994), the first biocompatible implant for hernia surgery, the first healthcare robot for neurosurgery and the first surgical navigation system

(Lettl et al., 2006). These examples show that independent innovators possess not only professional knowledge but also diverse and specialized technical-based solution-knowledge (Cohen & Levinthal, 1990). Specialized technical knowledge refers to the depth of the knowledge, while diversity refers to the breadth of it, both enhance creativity, new perspectives and insights concerning solutions (Boden, 1994; Fleming, 2007; Larkin et al., 1980; Lettl et al., 2009; von Hippel, 1998).

Lead users as external contributors have the freedom to think outside the box, including the non-mandatory obligation to innovate, a high degree of autonomy in the innovation process, less restricted mental models, and problem-solving standards, policies, core competencies, and inflexibilities of the company (Dahlin et al., 2004; Lettl et al., 2009; von Hippel, 2005). Companies tend to involve users in their radical innovations only when they possess high technical competencies (LaBahn & Krapfel, 2000; Lettl, 2007). Based on the reasoning above, we assume that lead users with high technical knowledge and skills have a positive impact on the success of the NPD process. Therefore, we formulate our next proposition as follows:

Proposition 2: High-level technical knowledge of lead users has a positive impact on the success of a lead user involved NPD

As stated above, lead users utilize their own "need-, and solution knowledge" to develop innovative ideas and products (Lüthje et al., 2005). During this utilization process they generally perform a necessary number of trial-and-error iterations and make adjustments immediately to prototypes if needed (Thomke, 1998). This experimentation process increases the speed and effectiveness of the NPD process compared to the traditional approach when a manufacturer firm builds up a prototype based on customer needs on its own. The problem-solving process of lead users through experimentation has an impact on the product's success and also on the competitive position of the company (Thomke et al., 1998; Thomke & von Hippel, 2002). As there is no reason to assume that the findings referred to above would not apply to medical innovations, we set the following proposition.

Proposition 3: The experimenter mindset of lead users contributes to the success of a lead user involved NPD

The design of breakthrough innovations depends on the generation of new knowledge (Dahan & Hauser, 2002; Mascitelli, 2000) created by the interplay of explicit and tacit knowledge (Nonaka, 1994). Explicit knowledge is objective, rational, embodied in a language, can be easily communicated, shared, stored in a form of written documents, while tacit knowledge is subjective and experiential, made up of mental models, values, insights, perceptions, beliefs, assumptions (Smith, 2001) and collected through subconscious experience (Zhang et al., 2015), experimentation, and learning by doing (Polanyi, 1966). Even though the articulation of tacit knowledge is difficult, it opens a new cognitive perspective (Polanyi, 1966) to solve challenging problems (Thomke & Fujimoto, 2000) and therefore, tacit knowledge is crucial for breakthrough innovations (Nonaka, 1994). According to Nonaka (1994), there are two modes of tacit knowledge conversation: tacit to explicit (externalisation), and tacit to tacit (socialisation). In the case of externalisation, metaphors, analogies and stories trigger the articulation of tacit knowledge (Lakoff & Johnson, 2003; Srivastva & Barrett, 1988; Stewart et al., 2006). Metaphors and stories help to generate and clarify complex ideas, enabling discussions to make the solution more understandable leading to novel product concepts (Sakellariou et al., 2017). In the case of socialisation, tacit knowledge is converted during the process of imitating and practising, observing in physical proximity and direct interaction with the receiver. While the tacit to explicit conversation through metaphors and storytelling requires an ability to narrate and capture the attention of the audience (Sakellariou et al., 2017), the tacit-tacit knowledge conversation needs a high level of collaborative attitude in lead users. We assume that communication skills and collaborative attitude both have a positive impact on the success of the NPD; therefore, we set the following proposition:

Proposition 4: A high level of communication skills and collaborative attitude has a positive impact on the success of a lead user involved NPD

Based on the propositions we assume that 1. expert-level of domain-related knowledge, 2. high-level technical knowledge, 3. experimenter mindset; 4. a high level of communication skills and collaborative attitude are essential characteristics of lead users and required for a successfully co-created NPD process. We co-evolved our propositions during our interviews by employing abductive reasoning to establish our final conceptual framework.

In the next section, we define some crucial terms and also describe each phase of the applied method in order to increase the conceptual clarity of the paper.

5.4. Methodology

5.4.1. Conceptual clarity

NPD is a process that describes the designated steps of firms that transform ideas into marketable products. The process consists of different stages including idea generation and concept formulation, product development, product testing and market diffusion.

We applied the basic definition of innovation by Oslo Manual: “An innovation is a new or improved product or process (or combination thereof) that differs significantly from the unit’s previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)” (OECD & Eurostat, 2018). We set a further criterion of innovation as the product shall be new-to-the-world, regardless of its complexity and its incremental or radical status.

We refer to the success of an NPD when the new product development process reaches the status of innovation reported by the chief executive of the company.

We describe the personal characteristics of a lead user as traits, attributes, skills, knowledge, attitudes, mindset, and other personal features that belong or relate to a particular person.

We refer to co-creation when lead users are participating at all stages of the NPD (Cooper, 2001; O’Hern & Rindfleisch, 2010) when the customer involvement is not restricted to a single point of idea exchange (Füller et al., 2012). This kind of collaboration is different from the broader understanding of co-creation, which refers to co-creation experiences (Prahalad & Ramaswamy, 2004, p. 8) as it includes the whole interaction with the customer and the firm and focuses on “creating an experience environment in which consumers can have active dialogues and co-construct personalised experience”.

5.4.2. Method

The authors performed case studies at five firms developing and manufacturing medical implants and prostheses or medical instruments as their core activity and core products. In terms of the engineering complexity of the products, three companies possessed low-complexity products, while two of them owned high-complexity ones. Abductive reasoning was applied to eliminate the weaknesses of inductive and deductive reasoning by using both induction and deduction cyclically. The study focuses on understanding lead users’ personal characteristics and their impact on the different stages of the NPD.

A theoretical sampling of companies was applied to enable a clear pattern recognition of the focal phenomenon, thereby providing a strong base for theory building (Eisenhardt & Graebner, 2007). For a case-study five companies were selected that develop and manufacture their own medical devices, are active participants in the global market, co-create with lead users in their NPD process and their new products cover the concept of the term of innovation defined in point 3.1. We conducted interviews with the managers participating both in the lead user selection and the whole NPD process.

We applied systematic combining for the simultaneous evolvement of the theoretical framework, fieldwork and case analysis. It means a process of "back and forth" between empirical observation and theory, which enables a deep understanding of both theory and phenomena. The outcome of our investigation might result in unexpected lead users' personal characteristics, leading in turn to the modification or extensions of our propositions. The process of systematic combining collaborates with the applied abductive reasoning through a highly iterative process between theory and practice which co-evolved our initial propositions and conceptual framework (Dubois et al., 2002). We conducted our interviews in three phases. In the first phase, we aimed to collect and analyse data, and in the second round our objective was to verify our interpretations of the required characteristics of lead users and identify their level of impact on the different stages of the NPD, and in the third phase we set out to embed our results in a theoretical framework.

Phase 1. Collecting and analysing data

Semi-structured interviews were performed about the phenomena within the defined real context. The process of data collection, analysis and validation proceeded in four main steps. In the first step, we became familiar with the organisational context in order to set the selection criteria for suitable interviewees (Patton, 2015). 1. They should have a decision-making position regarding the whole NPD process; 2. They should play an active role in the selection process of lead users. Considering the flat organisational structure of the identified firms, in each case, the interviewees were the general managers and the heads of the development department of the companies examined. A variety of job positions helped us to avoid bias in the ongoing retrospective sense-making process (Eisenhardt & Graebner, 2007; Weick et al., 2005). We created in advance a well-defined field procedure and a clear schedule for the data collection process. To ensure conceptual clarity, the interviewees were given a detailed explanation of the major terms on the basis of an interview protocol (Appendix A). The participants received the interview protocol in advance (Yin, 2018) with the aim of the interview, the definitions of all the essential terms, and the four initial propositions regarding lead users' characteristics in the form of semi-structured interview questions. The interviewees were asked to assess the four proposals and describe any characteristics which were not included in our protocol but may have an impact on the success of the NPD process. In the second documentation step, all interviews were transcribed in order to establish and strengthen the evolving theory (Yin, 2018) and sent to the interviewee to confirm the content of the collected data. After resolving any inconsistencies in our interpretations and becoming intimately familiar with each stand-alone case, we derived the first findings from each interview. In the third step, we made a within-case analysis (Eisenhardt, 1989), and described each interview as an intermediate step. Once we identified any characteristic elements of lead users, we marked them in the text with different colours. The same or similar characteristics were marked with the same colour in the case of each interview. In this process, we were unable to use any word processing software because the interviewees applied multiple metaphors or different expressions for the same characteristic elements and in such cases software does not seem to provide appropriate results. In the fourth step, we linked the findings from the five companies of the case-study and compared the identified characteristic elements to establish a list of categories. We carried out this process step by step. First, we identified a characteristic element; second, we looked for similarities in all the transcripts; third, we established a category when it appeared at least in the case of two companies. Finally, we read all cases again in order to verify the results of our within-case analysis. The process resulted in six categories, including four of our proposals, and two new characteristic elements.

We conducted altogether seven interviews in the case of Company A and C, and 8 in the case of Company B, D and E. The shortest interview took 1:00 hour and the longest 3:00 hours. Table 5.1. shows the details of the data collection sources and processes by each company.

Table 5.1. Data collection sources

	Company A	Company B	Company C	Company D	Company E
Core Products	medical implants and prostheses	medical implants and prostheses	medical implants and prostheses	medical instruments	medical instruments
Core Activities	development and manufacturing	development and manufacturing	development and manufacturing	development and manufacturing	development and manufacturing
Interviewee Positions	general manager and head of R&D	general manager and head of R&D	general manager and head of R&D	general manager and head of R&D	general manager and head of R&D
Engineering Complexity of the Products	low complexity	low complexity	low complexity	high complexity	high complexity
Total Number of Interviews	7	8	7	8	8
Interview duration interval (shortest - longest)	1:30-3:00	1:20-2:55	1:00-1:35	1:15-2:40	1:10-2:50

Source: own compilation

We considered the level of product complexity for each company. Therefore, we applied the term ‘engineering complexity’ in our study adopting the definition by Senders (2006). A product was considered highly complex when its operation required programmatic logic, otherwise, it was judged as low complexity.

Phase 2. Verification of our interpretations

Through the verification process, we asked our interviewees to check whether our interpretation is correct and if they want to skip or add something. As technical and market success represent different aspects of an NPD, we found it crucial to separate them and also investigate the contribution of each characteristic to the success of the new product development. Technical success refers to the status when the product has met the specification reported by the head of the R&D department. Market success stands for the status when the product has achieved the goals of the firm regarding profit, market acceptance and customer satisfaction evaluated by the firm and reported by the chief executive of the company. The term impact refers to the effect of a characteristic on the success of a certain stage of the NPD. The level of impact was judged based on the results of the focus group interviews.

We set one focus group at each company in order to obtain the interpretations of our results from the participants, i.e. the former interviewees (Morgan, 1997). The data collection was interactive (Flick, 2019) as the focus group setting allowed the participants to react immediately to each other’s responses (Stewart et al., 2006) in order to increase the reliability of our interpretations of the interview data. We presented the six categories from our case summary to the participants at each company (Yin, 2018) and entered into a discussion about them. The participants were asked to rate each characteristic element on a scale from one (strongly disagree) to five (strongly agree) in terms of their impact on the technical and market success of the product, as well as their impact on the success of each stage of the NPD process including the 1. idea generation and concept formulation, 2. product development, 3. prototype testing phase, 4. market diffusion stages. Each focus group discussion resulted in a score between one and five. At the end of the process, we assigned each company a score of the focus group discussion (A, B, C, D, E) and calculated the mathematical average (AVG) by each category in a separate response sheet (Table 5.2.).

Table 5.2. Response sheet including the impact of each characteristic

	IMPACT on the technical success						IMPACT on the market success						IMPACT on the idea generation and concept formulation stage						IMPACT on the product development stage						IMPACT on the prototype testing stage						IMPACT on the market diffusion stage					
	Firm						Firm						Firm						Firm						Firm						Firm					
Characteristics / scores by firms and average	A	B	C	D	E	*AVG*	A	B	C	D	E	*AVG*	A	B	C	D	E	*AVG*	A	B	C	D	E	*AVG*	A	B	C	D	E	*AVG*	A	B	C	D	E	*AVG*
Expert level of professional knowledge	5	1	5	4	5	*4*	5	5	5	3	3	*4,2*	5	5	5	5	4	*4,8*	4	1	4	2	3	*2,8*	4	5	5	4	4	*4,4*	5	5	5	4	2	*4,2*
High level technical knowledge	4	1	2	4	4	*3*	5	5	2	2	3	*3,2*	3	2	3	4	4	*3,2*	4	1	2	2	3	*2,4*	4	5	4	5	4	*4,3*	5	5	2	3	2	*3,4*
Experimenter mindset	4	3	4	5	4	*4*	3	1	5	3	4	*3,2*	4	5	5	5	3	*4,4*	4	1	3	3	4	*3*	4	5	5	3	4	*4,2*	5	1	5	1	1	*2,6*
Social and professional connectedness	4	1	2	4	5	*3,2*	5	1	5	4	4	*3,7*	4	3	4	4	5	*4*	4	1	2	3	4	*2,8*	4	1	2	3	4	*2,7*	5	2	5	4	4	*4*
Formal authority	5	4	1	2	1	*2,6*	5	5	5	4	4	*4,6*	5	1	3	3	1	*2,6*	5	1	1	2	2	*2,1*	5	3	1	4	1	*2,8*	5	5	5	5	4	*4,8*
Collaboration attitude and communications skills	5	5	3	3	4	*3,9*	5	5	5	4	4	*4,6*	5	5	5	4	4	*4,5*	5	5	2	2	4	*3,5*	5	5	5	3	4	*4,4*	5	5	5	4	5	*4,8*

Source: own compilation

We set three impact levels of each characteristic at different stages of the NPD. We marked certain personal characteristics *essential* (green highlighted fields) when the average score was between four and five inclusive of both values; *moderate* (blue highlighted fields) when the average score was between three and four inclusive of both values; *low* (no highlight) below the score of three.

The results verified our initial four propositions (1. expert level of professional knowledge, 2. high technical knowledge, 3. experimenter mindset, 4. collaboration attitude and communications skills) and also verified the two additional characteristic elements (5. social and professional connectedness, 6. formal authority) by the results of abductive reasoning. Furthermore, we considered the different complexities of the products before formulating our conclusion. The group discussions with the former interviewees led us to the conclusion to search and adopt a theoretical framework where we can embed and interpret our findings.

Phase 3. Embedding our results in a theoretical framework

After the verification of our propositions and interpretations, we started to search for complementary literature on the domain of our study to increase the relevance of our findings based on theoretical perspectives (Ridder et al., 2014). We considered applying the extended version of the lead user method referred to as Lead User Cognition (LuCog) method (Venesz et al., 2022), which fits well with our findings as the method focuses on lead users' personal characteristics at different stages of the NPD process and is well-grounded by 45 empirical studies published between 2000 and 2020. The method enabled us to interpret the results in a dedicated context of medical device innovations and demonstrate the relevance and novelty of our findings by making a contribution to theory and practice by offering managerial contributions.

In the next section, we describe our findings regarding the six personal characteristic elements associated with lead users.

5.5. Findings

The central findings of our research refer to the identified lead users' characteristics and their impact on the success of the NPD process. We have found that each characteristic has a different impact at the various stages of the NPD process, and the same lead user must be involved in the same NPD process.

Based on our findings we accepted Proposition 1 (expert level of domain-related knowledge), Proposition 2 (high-level technical knowledge), Proposition 3 (experimenter mindset), and Proposition 4 (high-level of collaboration attitude and communications skills) and extended the list of characteristics with an additional two by applying abductive reasoning: 5. Social and professional connectedness, and 6. status of formal authority.

In our analysis lead users were homogenous regarding their successful contribution to the NPD process and their characteristics including all six elements.

In the following part of this section, we reveal the results of the data analysis providing answers also to RQ2.

Expert level of domain-related knowledge

The relevance of professional knowledge was reported by all case companies as one of the main characteristics of lead users. Based on the key attributes of lead users captured in the interviews and focus group discussions we were able to link lead users to individuals at the "expert" stage of the Novice to Expert model (Dreyfus, 2004; Dreyfus & Dreyfus, 1980) for the purpose of gaining a further understanding of external contributors. The link was set up between the *attributes of the model* (bold letters) and the excerpts from interviews (in brackets) including *authoritative knowledge* (deep tacit knowledge), the *standard of work* (intuitive decisions), *dealing with complexity* (holistic understanding of complex situations), *perception of context* (seeing the overall big picture), a*utonomy* (thinking out of the box and breaking rules).

> "They are specialists in their field and have no less than ten to fifteen years of professional experience" (Company A). "They are active academic researchers with considerable scientific results." (Company D). "Innovation with practitioners with less than ten years of experience usually comes to a dead-end" (Company E). "They possess a deep level of product-, and use-knowledge and are able to determine a significant problem of the product and create an innovative vision for the solution" (Company A). "They see the overall picture of the system and try to emphasize and focus on important aspects" (Company D). "… act and decide intuitively" (Company B). "They are able to think out of the box and break rules" (Company D).

We discovered a threshold level with the age of individuals when the motivation and the efficiency of the contribution begin to fall.

> "Even though long years of experience determine considerable experience, there is a threshold level at the age of 60-65 when practitioners become less motivated, and the contribution becomes less efficient" (Company B). "At this age, they mainly fulfil the decision-making roles on professional committees and advisory boards and are less interested to innovate" (Company D).

Based on the result of our data analysis, we have found that an expert level of domain-related knowledge is essential to achieve market and technical success of the new product. It is also essential in the first, third and fourth stages of the product, while it has a moderate impact on the second stage of the NPD process and thus we accept Proposition 1.

High level of technical knowledge

A high level of technical knowledge enables users to propose feasible solutions, extend the variety of possible solutions, do early experimentation and test their initial idea by developing their own prototypes. Interestingly, we have found that technical knowledge has a low impact on the product development stage as firms generally rely on their own R&D resources and do not require additional resources from external contributors. The results of our analysis show that technical knowledge is essential in the prototype testing phase as only technically competent lead users are able to communicate effectively with product engineers by providing valuable feedback and feasible suggestions.

> "A high level of technical knowledge is a huge advantage, as it extends the variety of the possible solutions, and involves a wider perspective of solutions" (Company B). "Technically savvy individuals possess better worked-out and feasible ideas" (Company E). "Individuals with technical knowledge accept the reasoning of engineers more easily and do not push technically unfeasible ideas" (Company D). "The best technical contributors have a technical mindset, are interested in technical solutions, possess a small workshop at home, and do informal learning" (Company D). "They are able to convince potential future users or decision-makers by providing correct technical reasoning" (Company C).

Based on the result of the data analysis we have experienced that a high level of technical knowledge has a moderate impact on the technical and market success of the products and has a moderate impact on the first and third, a low impact on the second and an essential impact on the third stage of the NPD. Consequently, we accept Proposition 2.

Experimenter mindset

Our research data has revealed two important findings. On the one hand, the recurring process of experimentation in the idea testing and prototype problem-solving processes leads to a significant improvement of the initial idea or prototype and consequently has a positive impact on the NPD. On the other hand, willingness to experiment demonstrates lead users' high motivation level to realize the idea in the form of a new product.

> “…the initial testing “trial-error” process helps practitioners to advance their idea by applying plasticine, metals and woods. The capability to draw, the manual skills and experimenter mindset highly contribute to the success of NPD” (Company E). “…such a person shows a high motivation in the whole NPD process” (Company B). “Practitioners with experimenter mindsets can be further characterized by a high level of commitment, technical and manual skills.” (Company D). “… the process of experimentation requires advanced domain-specific knowledge and technical competencies” (Company A).

We have come to the conclusion that an experimenter mindset is essential to reach technical success, while it has a moderate effect on the market success of the new product. It is essential at the first and third stages and has a moderate impact on the second phase and a low impact on the last stage of the NPD process.

Social and professional connectedness

The result of our data analysis indicates two significant findings. Firstly, we have found that socially connected users may gain valuable input and information from other practitioners on how to improve an innovative idea or solution. Users’ creativity is also enhanced in social networks, which is essential to create new ideas by gaining access to diverse knowledge bases from other participants. Social connectedness plays an essential role in the market diffusion stage of the NPD by facilitating the promotion of the product. Our verified interpretations have proved that social connectedness is essential in the idea generation and market diffusion phases, while it has a low impact on the product development and prototype testing phases.

> “…it helps fine-tune initial ideas by getting immediate responses from experienced practitioners and possible future users.” Company (E). “Socially connected users are well informed about market trends and real demands of users, which allow us to reduce the time-to-market ratio and develop products based on real market demand” (Company D).

Secondly, we found that social connectedness enables users to gain valuable information about market trends, needs, and existing solutions; therefore, it fosters the market familiarity of lead users.

> “A well-performing contributor is familiar with the competitors and available products on the local and global market.” (Company E). “They know in advance how to exploit

> the product advantages in their own practice, and are aware of the commercial potential of the market." (Company C). "It is challenging if the practitioner is not familiar with the global market and leading trends, and wants to realize a product which cannot be sold." (Company B). "International work experience has a positive impact on the personal point of view to see the same problem from different aspects" (Company A). "Each market has its own speciality, regulations, medical standards, culture etc.; therefore, the right understanding of the target market and its context is crucial" (Company D).

Based on the result of our data analysis we have found that social connectedness has a moderate impact on technical and market success, while it is essential at the first and last stages, and it has a low impact at the second and third stages of the NPD.

Status of formal authority

The result of our data analysis indicates that lead users' status of formal authority is essentially important in order to change existing medical protocols and guidelines, influence the market in the promotion phase of the new product and trigger changes in mindset. The status of formal authority is derived from the job position and academic achievements of individuals. Diverse sales territories might require different formal authorities as their power might be restricted to a dedicated area or product.

> "The credibility of practitioners derives from their job position and academic achievements. The status of formal authority is necessary to be able to change existing medical protocols and guidelines" Company (E). "The market accepts a radically new product more easily if it is demonstrated by a formal authority" (Company D). "The power of the formal authority can be limited to a country or region; therefore, different authorities might be needed in different sales areas." (Company D). "A formal authority is very influential at conferences by promoting new innovative products and is able to make changes in mindset" (Company C).

Based on the result of our data analysis we may conclude that the status of formal authority of lead users is essential to reach the market success of the new product. We found this characteristic essential at the market diffusion stage of the NPD while at the other stages it had a low impact.

High level of collaboration attitude and communications skills

The results of our analysis demonstrate the importance of lead users' collaboration attitude and communications skills during the whole NPD process. Only users with a high level of communication skills are able to express their ideas and solutions by using a common language with product engineers as they use clear sentences and emphasize the essence of a problem or solution. Users with a high collaborative attitude regularly involve product engineers in real operations to show the context and also to express themselves in the process of "learning by doing".

> "Good communication skills are a must to share ideas, collaborate with engineers during the NPD process, and also communicate the product advantages during the market diffusion phase" (Company A). "Practitioners with excellent communication skills can enormously increase the efficiency of the co-creation as they can compose clear sentences and emphasize the essence of their insights during the whole NPD process. They show how they work, what the context is" (Company D). "Practitioners involve engineers in real surgical operations, which also represents their commitment to carrying out the idea in co-creation" (Company A).

Based on the result of the data analysis we may state that a high level of collaboration attitude and communications skills have a moderate impact on the technical success, while it is essential to achieve the market success of the product. Furthermore, it is essential at each stage of the NPD except the second stage where it has a moderate impact.

5.6. Discussion

In this article, we have reported the findings from interviews with five case companies in the context of medical device innovations and demonstrated that the personal characteristics of an external contributor would likely determine the success of the NPD. Next, we discuss our findings by reflecting on the existing literature and considering the generalization of our results.

Level of lead users' involvement in the co-created NPD process

According to (Venesz et al., 2022), most scholars discuss the personal characteristics of lead users only in connection with the idea generation stage at the fuzzy front end of the NPD. A limited number of studies have been found which investigate the required characteristics at the later stages of NPD. Our findings demonstrate a new insight into our specific context as a lead user needs to be involved in each stage of the NPD process (answering RQ1). Furthermore, the co-creator must possess all identified personal characteristics in order to reach success in the NPD process. Our findings indicate what characteristics are required at a certain stage of the new product development process. Based on the results, we also emphasize that the same lead user needs to own all the six characteristics and the same person needs to participate in all stages of the NPD.

Expert level of domain-related knowledge (need knowledge)

The findings of our study corroborate the scholars' statements about the importance of lead users' domain-related knowledge to discover innovation opportunities and develop novel solutions (Faullant et al., 2012; Lettl et al., 2006; Piller & Walcher, 2006; von Hippel, 1994). Studies apply different expressions to highlight the relevance of knowledge like "in-depth knowledge" (Lettl et al., 2006), "right amount of knowledge" (Faullant et al., 2012), "reach real-world understanding" (von Hippel, 1986, p. 797). Our study yields more specific insights to enhance the current understanding of lead users' knowledge by employing the "Novice to Expert" model (Dreyfus, 2004; Dreyfus & Dreyfus, 1980). Based on our findings we consider lead users as experts in their domain and apply the description of the "Novice to Expert" model and state that the right lead users are able to deal with complexity (components - refer to the elements of the situation the individual is able to perceive), able to determine and focus on significant aspects of the problem (perspective – able to choose the important elements to focus on), able to create an innovative vision for a solution without effort (commitment – understanding how to address the issue), and rely on their intuition to solve a problem without thinking of which principle, skill or theory to use (decision – a decision how to act).

Our findings indicate that expert knowledge is essential in the idea-generation phase that might be derived from the evidence that expert knowledge in the domain and thus intuitive feeling-based decisions enable users to make accurate predictions to generate new product ideas (Pham et al., 2012). The experts' ability to see the overall big picture, moving between analytical and intuitive grasp which allows them to see "the essence" (Dörfler & Eden, 2019) might trigger the positive contribution of a lead user in the prototype testing stage. The involvement of lead users in the market diffusion stage is also essential as they can achieve excellence with ease in the process of negotiation and promotion by utilizing their deep holistic understanding of the domain and the ability to go beyond existing interpretations.

Although we might think that the higher the acquired knowledge, the higher the innovation opportunity the lead user will explore and thus create new innovative ideas, we recognised a threshold level at the age of 65 for lead users when motivation and the efficiency of the contribution begin to fall. There might be two reasons that explain this phenomenon. The first argument might be that higher knowledge of users diminishes the ability to formulate radical ideas (Magnusson, 2009; Schienstock & Hämäläinen, 2001) as well as the U shape relation between creativity and knowledge (Amabile, 1983; Nickerson, 1999; Weisberg, 1999). The second explanation might be that practitioners of this age mainly fulfil decision-making roles on professional committees and advisory boards and are hence less interested to innovate.

High-level technical knowledge (solution knowledge)

The findings of our study further advance the general statements of scholars that the technical knowledge of lead users plays an important role in the NPD process (Enkel et al., 2005; Lüthje et al., 2005; Urban & von Hippel, 1988; von Hippel et al., 1999) by yielding more specific insights. On the one hand, technically-savvy users are able to do early experimentation, testing ideas by developing their own prototypes and consequently reducing unfeasible ideas. On the other hand, users with technical competencies are able to extend the variety of solutions and involve wider perspectives. Their technical knowledge can also be utilized at the prototype development stage by providing technically accurate feedback to product engineers and thus reducing the time and cost of the NPD process. While Gruner & Homburg (2000a) pointed out a negative impact of technically attractive contributors, our findings, in contrast, indicate that the technical knowledge of lead users is essential in the prototype testing phase and has a moderate effect on the idea generation and concept formulation stages. Technical knowledge can also be exploited at the market diffusion stage as lead users are able to provide technical reasoning and thus convince possible future customers.

Experimenter mindset

According to Thomke (1998), experimentation is an iterative trial-and-error learning process consisting of four steps: building a prototype, testing it in a real environment, analysing the findings and implementing improvements that are traditionally carried out by the firm. Similarly, the iterative trial-and-error process in the medical context is also crucial but with a major difference, i.e. experimentation on humans is prohibited. Furthermore, the process of experimentation is carried out by the lead user alone or in collaboration with the firm by focusing on idea testing, early prototype building and advancement and prototype testing (on animals) phases. As our findings have indicated the experimenter mindset is strongly linked to lead users' technical knowledge; therefore, these characteristics shall be considered in a complex way. Furthermore, we derive two important implications from our findings. Firstly, the experimentation mindset of lead users presupposes high domain-related knowledge and technical knowledge, and secondly, individuals with an experimenter mindset demonstrate high motivation levels to implement the idea by providing a meaningful contribution to the NPD process.

Social and professional connectedness

Considering the specific context of medical device innovations, our results confirm the importance of social connectedness to achieve success in innovation (Dahl & Moreau, 2002; Hanson & Putler, 1996; Kratzer & Lettl, 2008). We sought to provide some novel insights as investigation on social connectedness seems to be neglected in lead user research. Our findings have indicated that social connectedness is essential to expect and deliver valuable ideas and gain feedback from experienced practitioners and possible future users on how to improve an innovative idea or solution. It also plays an essential role in the market diffusion phase of the NPD as medical practitioners are likely to accept solutions from a lead user with the same professional background especially when the lead users are respected persons based on their academic achievements and their status of formal authority. The wide social connectedness of lead users extends their market familiarity, which facilitates their ability to accurately predict future market needs and trends ("ahead of market trend").

Status of formal authority

In contrast with the original lead user concept which suggests involving lead users only in the idea generation and concept formulation phase (von Hippel, 1986), our findings imply that the involvement of lead users in the diffusion stage is essential to achieve market success for the new product. The necessity is derived from the evidence that in the medical context only a formal authority is able to change the existing medical protocols and guidelines to introduce innovation into everyday practice. Furthermore, the market may accept an innovation more easily when it is presented by a respected and credible practitioner based on their status of formal authority. Our findings provide a novel approach as the investigation of lead users at the market diffusion stage is highly neglected in the academic literature. From a more general aspect and within a different market context, we can state that the socially and professionally respected position of lead users might facilitate the market diffusion of an innovation.

High level of collaboration attitude and communication skills

Expert lead users' knowledge is likely to be tacit (Dreyfus, 2004) and therefore sticky (Lüthje et al., 2005) hence there is some difficulty in its articulation (Polanyi, 1958). Our findings suggest that right lead user utilizes both ways of tacit knowledge conversion as a tacit to explicit and a tacit to tacit. The former requires a high level of communication skills to emphasize the essence of their insights through telling stories and simple sentences, while the latter requires a high collaborative attitude from lead users, which expresses their intention to involve product engineers in real surgical operations to show what they cannot express otherwise in words. Our findings imply that such lead users possess high motivation levels and commitment to conceive an idea and realise a new product.

5.7. Conclusion

Even though the original lead user method set two criteria for lead users as "ahead of market trend" and "high expected benefit", empirical studies show that the identification process of lead users is rather weak (Lüthje & Herstatt, 2004), thus it requires some evidence-based guidance. In the theoretical contribution part of this section, we show how the identified characteristics are linked to the general characteristics of lead users (answering RQ3) thus decreasing the uncertainty of the selection process of lead users. In the practical contribution part, we refer to the degree of involvement and impact of product complexity on the requested characteristics. In the managerial contribution part, we indicate signals of each lead user characteristic that can be applied in everyday practice through the identification and selection process.

Theoretical contribution

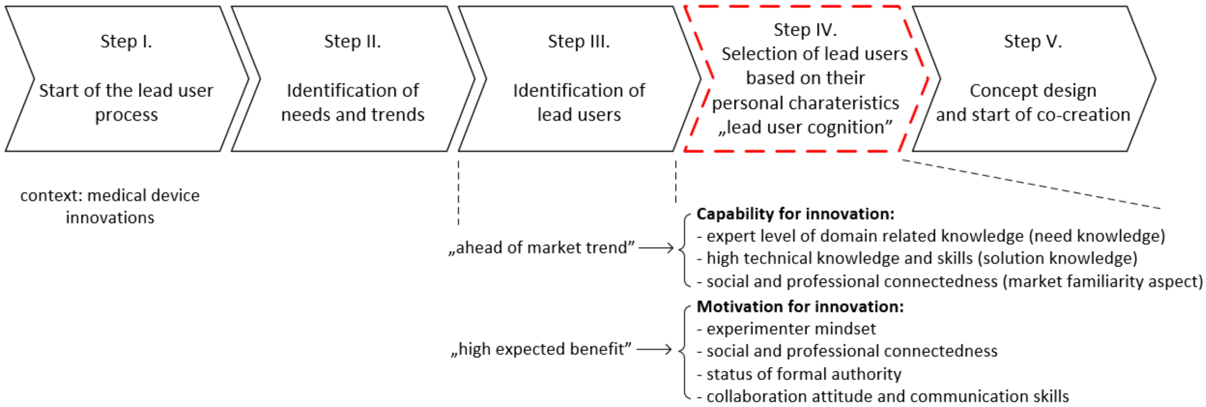
To select lead users based on their first general characteristic of 'ahead of market trend', "one must identify the underlying trend on which these users have a leading position" (von Hippel, 1986, p. 798). Despite the existence of formal methods ranging from the intuitive judgement of experts to simple trend extrapolations, the "trend identification and assessment remains something of art" and additionally, "these perceptions may not be consistent over time" (ibid). Empirical studies also emphasize that it is difficult to select reliable information sources and prioritize pieces of information especially when the knowledge and the experience of the experts are highly heterogeneous (Lüthje et al., 2003; Lüthje & Herstatt, 2004). Furthermore, the identification of trends might mislead the management in the case of breakthrough innovations. This is based on the argument that in history there were no existing trends to identify in the case of radical innovations like the X-ray machine, stethoscope, antibiotics, cardiac defibrillator etc.

In order to decrease trend prediction uncertainty, we propose a different way of identifying trends and consequently lead users by using the following line of argumentation. According to (Pham et al., 2012) the intuitive feelings of individuals with an expert level of knowledge of the prediction domain lead to high accuracy when predicting the future. Moreover, Hogarth (2005) states that the intuitive form of judgment outperforms the analytical processes where the analytical complexity is high, and where it is difficult to identify any single formal rule that has high predictive validity. Furthermore, individuals who have developed a high level of domain-related knowledge through education and work experience will more likely to discover an innovation opportunity than others (Shane, 2000). Based on the above reasoning, we have a strong argument to state that lead users with 1. expert level of domain-related knowledge (need knowledge) and 2. high-level technical knowledge (solution knowledge), and 3. market familiarity (derived from social and professional connectedness) are more likely to predict market trends than traditional trend assessment methods or internal/external market researchers (Figure 2).

The second general characteristic of lead users is the "high expected benefit", which refers to the benefit by obtaining the solution (von Hippel, 1986). The expected benefit triggers users' motivation to develop early prototypes and perform cycles of experimentation. The conversion of tacit-to-tacit assumes a high level of willingness to collaborate with product engineers, while the tacit-to-explicit conversion requires personal effort to share ideas informally through personal discussions and storytelling (Collins, 2001). The status of formal authority and social and professional connectedness might be considered as a facilitator in the process of obtaining high expected benefits. Based on the above line of reasoning we have a strong argument to state that the high expected benefit of lead users can be associated with their personal characteristics including 1. experimenter mindset, 2. social and professional connectedness, 3. status of formal authority, 4. collaboration attitude and communications skills (Figure 5.1.).

In order to increase the efficiency of the lead user concept, we elaborated the method by adapting the "lead user cognition" partial method and integrated our findings into the identification and selection phases of the method and linked the characteristics discovered to the general attributes of lead users as "ahead of market trends" and "high expected benefit".

Figure 5.1. Elaboration of the lead user method



Source: own compilation

In conclusion, the properly selected lead users are able to be "ahead of market trends" based on their ability to identify market trends, and also capable of complying with the characteristic feature "high expected benefit" as well as contributing to the success of the NPD.

Managerial implications

In contrast with the existing literature concerning the various degree of lead user involvement in NPD (Brockhoff, 2003; Enkel et al., 2005; Gruner & Homburg, 2000; von Hippel, 1986), our findings suggest that it is essential to involve lead users in each phase of new product development as each characteristic is essential in all phases of the NPD process (Table 2.) to reach technical and market success of the new product. In Table 3 we summarised the main attributes of each characteristic and described how they contribute to the success of the NPD process.

Our findings indicate a novel approach, i.e. there is no difference in the impact of the characteristics concerning the complexity of the product. It means that all characteristics of lead users are essential to achieve the success of the NPD in the case of low as well as high-complexity products.

In order to ease the selection of proper lead users, we identified signals (Table 3.) that enable decision-makers to assess the certain characteristics of lead users. We avoided applying unmeasurable signals like "tacit knowledge" which are not tangible and thus have no managerial implications. The assessment of each proposed signal shall be considered as a key factor of judgement during the conversation with lead users in the initial workshop. The table contains three sections 1. it describes the main attributes of each lead user's personal characteristics adapted from our findings; 2. it explains how each element contributes to the success of NPD ("The lead user is able to…"); 3. it provides signals for NPD managers to select appropriate lead users based on objective criteria. The early application of the signals enables managers to select the appropriate lead users thereby increasing the possibility of a successful co-created NPD process.

The paper has already discussed the descriptions and the relevance of each signal in the previous chapters.

Table 5.3. Main attributes of each characteristic, their contribution and signals for practices

		idea generation and concept formulation stage	product development stage	prototype testing stage	market diffusion stage
Expert level of domain-related knowledge	what are the main attributes of these characteristics?	possess deep tacit understanding across the area of practice able to switch between analytical and intuitive processes able to see the big picture holistic grasp of complex situations capable of determining and focusing on a significant aspect of the problem create an innovative vision for the solution without effort rely on intuition to solve a problem without thinking about which principle, skill or theory to use			
	how does it contribute to the success of NPD (where is it significant or moderate) The lead user is able to...	determine and/or set market trends focus on the significant problem identify real market needs (need knowledge) create an innovative vision for the solution		consider the professional aspects of the problem provide feedback by considering the professional aspects of the solution	facilitate the market diffusion process through professional credibility
	how to discover (signals for practices of managers)	min. 10-15 years of experience in the domain age below 65 existing scientific results, patent(s) academic researcher status and achievements number and relevance of existing patent(s) thinking out of the box and breaking rules			
High level technical knowledge	what are the main attributes of these characteristics?	technical competencies extends the variety of possible solutions, and involves a wider perspective of solutions accept more easily the reasoning of engineers don't push technically unfeasible ideas possessing a technical mindset			
	how does it contribute to the success of NPD (where is it significant or moderate) The lead user is able to...	present worked-out ideas propose technically feasible solutions (solution knowledge)		consider the technical aspects of the problem provide feedback by considering the technical aspects of the solution	provide adequate technical reasoning about the solution
	how to discover (signals for practices for managers)	use the right technical terminology interested in technical solutions have a technical mindset practise informal learning regularly			

Experimenter Mindset	what are the main attributes of these characteristics?	high level of commitment high level of motivation advanced manual skills			
	how does it contribute to the success of NPD (where is it significant or moderate) The lead user is able to...	test the initial idea and build own prototype(s) advance the idea through experimentation make drawings		make experimentation on prototypes and provide professional and technically proper feedback	
	how to discover (signals for practices of managers)	initial experimentation activity existence of own build an early prototype possess workshop at home			
Social and Professional Connectedness	what are the main attributes of these characteristics?	in the central position in a relevant social and/or professional group			
	how does it contribute to the success of NPD (where is it significant or moderate) The lead user is able to...	expect and deliver valuable ideas to the participants become familiar with alternative ways of thinking advance initial ideas get responses from experienced practitioners facilitate and promote access to diverse knowledge bases (driving force of radically new ideas) gain information about market trends and real demands of users			facilitate the market promotion of the product
	how to discover (signals for practices of managers)	the role and central position in a relevant social and/or professional group			

<table>
<tr><td rowspan="3">Status of Formal Authority</td><td>what are the main attributes of these characteristics?</td><td colspan="4">empowered position of an organisation</td></tr>
<tr><td>how does it contribute to the success of NPD (where is it significant or moderate)

The lead user is able to...</td><td></td><td></td><td></td><td>influence professionals through credibility
change existing clinical protocols and guidelines
be very influential in promotion
make changes in mindset</td></tr>
<tr><td>how to discover (signals for practices of managers)</td><td colspan="4">decision-making position
academic status and achievements
high level of job position</td></tr>
<tr><td rowspan="3">Collaboration Attitude and Communications Skills</td><td>what are the main attributes of these characteristics?</td><td colspan="4">tacit to explicit and
tacit to tacit conversion</td></tr>
<tr><td>how does it contribute to the success of NPD (where is it significant or moderate)

The lead user is able to...</td><td>convert tacit knowledge to explicit by sharing ideas, the essence of insights through clearly composed sentences, use obvious metaphors
show the context of work for product engineers</td><td></td><td>make tacit to tacit conversion by involving engineers in real surgical operation imitating and practising, observing in physical proximity and direct interaction with product engineers</td><td>demonstrate clear communication in the diffusion phase of the new product (avoiding special expressions, non-obvious metaphors etc.)</td></tr>
<tr><td>how to discover (signals for practices of managers)</td><td colspan="4">express high motivation to show the problem in a real environment
use simple, clear, understandable communication
apply obvious metaphors and expressions in communication</td></tr>
</table>

Source: own compilation

To conclude, our findings suggest that the characteristics of lead users are crucial to achieving success in NPD; therefore, their consideration is important in the selection process. In order to achieve this goal, the following hurdles need to be overcome. First, managers must be aware of the importance of the personal characteristics of lead users. Secondly, the selection process should be based on the six characteristic elements of lead users by applying the proposed signals in the assessment process of lead users.

Limitations and further research

Our study is subject to limitations that might impact the research findings. The study is based on some case study research and a qualitative approach. We applied theoretical sampling, systematic combining and abductive reasoning. The investigation was conducted at the individual level with the involvement of a single lead user. We have not examined the case when multiple lead users participate in the NPD process as it sets up a different situation and might require other or additional characteristic elements from the participants. Another limitation is that we have investigated individuals who fulfil the criteria of lead user as "ahead of market trend" and "high expected benefit" (von Hippel, 1986). Our study is restricted to the context of medical device innovations.

Further research might apply quantitative research methods and other approaches in order to confirm our findings. The investigation of multiple lead users on the same lead users involved in NDP opens new research opportunities to identify other characteristic elements and provide new implications. A further investigation might provide new results if the definition of external contributors is not restricted to the two general attributes of lead users defined by the lead user concept (von Hippel, 1986). The different contexts might require a different set of personal characteristics, thereby proposing an interesting future research agenda.

Appendix A - Interview Protocol

Name of the interviewee(s):
Position(s):
Company:
Date:
Start time:
Finish time:
Interviewer(s):

RQ1: How comprehensively does a lead user need to be involved in the co-created NPD process?

RQ2: How do the different personal characteristics of lead users affect the success of the NPD?

RQ3: How can the identified personal elements be linked to the general characteristics of lead users as "ahead of market trend" and "high expected benefit"?

We defined four stages of the NPD process including 1. idea generation and concept formulation, 2. product development, 3. prototype testing, and 4. market diffusion.

The expected result of our research will facilitate the identification and selection process of lead user for new product development in collaboration with the external contributor.

We will conduct a semi-structured interview related to the proposed two personal characteristics, but we are also interested in additional lead users' characteristics that have an impact on the success of the NPD process. We do our interview in two rounds, in the first phase we collect all personal characteristics of lead users, and in the second phase, we will assess the impact of each characteristic at the different stages of the NPD process.

In order to ensure conceptual clarity, we first define some fundamental terms.

Lead users:

- "lead users face needs that will be general in a marketplace – but face them months or years before the bulk of that marketplace encounters them, and
- lead users are positioned to benefit significantly by obtaining a solution to their needs and so may innovate."

New product development (NPD):

- NPD is a process that describes the designated steps of firms that transform their idea into marketable products. The process consists of different stages including idea generation, concept formulation, product development, product testing and market diffusion.

Innovation

- The term defined by the Oslo Manual: "An innovation is a new or improved product or process (or a combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)" (OECD & Eurostat, 2018). We set a further criterion of innovation as the product shall be new-to-the-world regardless of its complexity and its incremental or radical status.

Success:

- We set the term of success when the new product development reaches the status of innovation.

Product complexity:

- We apply the term 'engineering complexity' in our study and adopt a definition by Sender (J. W. Senders, 2006). A product is considered highly complex when its operation requires programmatic logic, otherwise, it is judged as a product with low complexity.

Personal characteristics of a lead user:

- The term involves traits, attributes, skills, knowledge, attitudes, mindset and other personal features that belong or relate to a particular person.

Co-creation:

- We refer to co-creation when lead users are actively participating in all stages of the NPD. This kind of co-creation is different from the broader understanding of co-creation which refers to co-creation experiences as it includes the whole interaction with the customer and the firm and focuses on "creating an experience environment in which consumers can have active dialogue and co-construct personalised experience". In our case co-creation is also different from customer involvement to a single point of idea exchange

Our investigation is restricted to lead users involved in the new product development process, which means that other sources of innovation are beyond the scope of our research.

Semi-structured interview questions:

1. What do you think about the impact of the domain-related knowledge of lead users on the success of the NPD process?

2. What do you think about the impact of technical knowledge and skills of lead users on the success of the NPD process? (Technical competencies would refer to the technical knowledge, skills and manual dexterity of lead users.)

3. Can you describe any further personal characteristics of lead users that have an impact on the success of the NPD process which has not been discussed so far in our interview?

6. Contribution

6.1. Selecting appropriate lead users: the lead user cognition method

In the systematic literature review, we found that most of the studies focus only on the idea generation stage of the NPD, and they discuss mainly the personal characteristics of lead users only in connection with the fuzzy-front-end phase of the new product development process. Consequently, a limited number of studies were found, which discuss the characteristics of users at the later stages of NPD. The finding indicated also that firms generally rely on their own technical expertise and do not require any additional contributions from users or cooperate with users only with high technological competencies and involve them in the product development phase.

Our first article answers RQ1 of “What lead users’ personal characteristics should be accounted by a decision maker in the selection process of lead users by considering each stage of the NPD process and the differences between the consumer and industrial segments?”

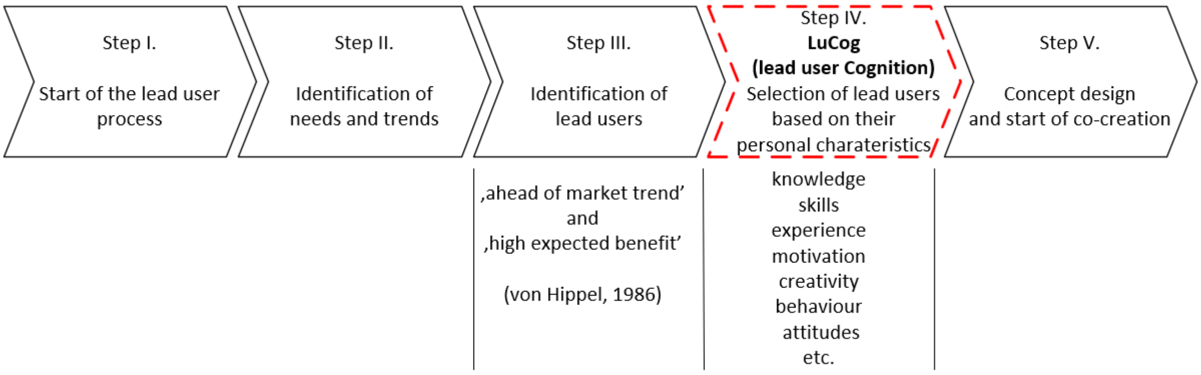
In order to respond to the research question as well as fulfilling knowledge and also a research gap, a systematic literature review was performed to provide an overview of lead users’ personal characteristics at different stages of the co-created NPD process. 45 primary studies were found by the results of applying automatic and manual search processes, inclusion and exclusion criteria, and conducting a quality assessment process. The selected studies were organized into two categories, e.g., consumer and industrial contexts, as they provided the key research settings of the studies. The found characteristic elements were categorised and attached to the different stages of the NPD process including 1. idea generation, 2. concept formulation, 3. prototype and product development and testing stages, and 4. market diffusion.

The identified 45 primary papers were highly heterogeneous in terms of the contexts of investigation (consumer or industrial), type of users (user or customer), level of users’ involvement (only in the fuzzy front end of the process or subsequent stages of the NPD) and type of corresponding products like kite surfing (Franke, von Hippel and Schreirer, 2006), basketball shoes (Füller, Jawecki and Mühlbacher, 2007), mountain bikes (Lüthje, Herstatt and Von Hippel, 2005), industrial products (LaBahn and Krapfel, 2000a). We found additionally that the characteristics of the external contributors strongly vary, different user characteristics are needed in different market contexts, and different characteristics are required at different stages of the NPD. No studies were found that investigate the needed elements at the market diffusion stage of the NPD. Figure 4.4. and Table 4.7. provides an overview of our research results while Table 4.8. summarize the identified differences of lead users between the consumer and industrial segments.

The result of our first paper indicated that the personal characteristics of lead users play a crucial role in the NPD process of producer firms, but the level of users' involvement and the required characteristics vary in different stages of the NDP. We found additionally that the identification process (step III.) of the lead user method is not suitable to select the right lead users as the lead user method does not consider explicitly the personal characteristics of lead users. Thus, we elaborated the lead user method and included an additional step that aims to select the right external contributors by considering their personal characteristics as enable factors of the successful co-creation process. The importance of the extension is based on the evidence that the proper selection of lead users for co-creation might reduce the innovation-related costs and the time-to-market ratio besides increasing the quality of the new product.

Based on the above reasoning we made a contribution to the lead user method by extending it with a partial method called "lead user cognition" which is an additional step between the stages of "identification of lead users" and "concept design and start of co-creation as Figure 6.1. shows. The lead user cognition method refers to the cognition process of decision-makers during the selection of lead users by taking into account their personal characteristics.

Figure 6.1. The lead user method



Source: own compilation

6.2. Identifying the impact of lead users' characteristics in each stage of the NPD process

To answer RQ2 (What personal characteristics can be associated with lead users and how do they impact in each stage of the NPD process?) we performed a case study at five medical device developers and manufacturer firms. We applied the abductive approach to eliminate the weaknesses of inductive and deductive reasoning by using both induction and deduction cyclically.

We employed theoretical sampling of companies to enable a clear pattern recognition of the focal phenomenon and that provides a strong base for theory building (Eisenhardt and Graebner, 2007). We selected five case companies that develop and manufacture medical devices, and are active participants in the global market, co-create with lead users in their NPD process and the new product fulfils our applied term of innovation. We used systematic combining where we evolved simultaneously the theoretical framework, fieldwork and case analysis. The outcome of our investigation might result in unexpected lead users' personal characteristics, leading in turn to the modification or extensions of our propositions. The process of systematic combining collaborated with the used abductive reasoning through a highly iterative process between theory and practice which co-evolved our initial propositions and conceptual framework (Dubois *et al.*, 2002). We conducted our interviews in three phases. In the first phase, we aimed to collect data, in the second step to verify our interpretations of the required characteristics of lead users and also identify their level of impact on different stages of the NPD, while in the third phase to embed our results in an existing theoretical framework of lead user cognition.

The main findings of our research refer to the relevance of six personal characteristics of lead users in achieving technical and market success of a new product and also their impact on each stage of the NPD process. In our analysis lead users were homogenous regarding their successful contribution to the new product development and concerning their characteristics including 1. expert level of domain related-knowledge, 2. high-level technical knowledge, 3. experimentation mindset, 4. social and professional connectedness, 5. status of formal authority, 6. high communication skills and collaborative attitude.

Our study yields more specific insights to understand the level of lead users' knowledge by employing the "Novice to Expert" model (Dreyfus and Dreyfus, 1980; Dreyfus, 2004). We found that appropriate lead users are able to deal with complexity, able to determine and focus on significant aspects of the problem, able to create an innovative vision for a solution without effort and rely on their intuition to solve a problem without thinking of which principle, skill or theory to use.

In contrast with the existing literature that concluded the various degree of lead user involvement in the NPD (von Hippel, 1986; Gruner and Homburg, 2000a; Brockhoff, 2003; Enkel, Perez-Freije and Gassmann, 2005) our findings suggest that it is essential to involve lead users to each phase of new product development as each characteristic is essential in all stages of the NPD process to reach technical and market success of the new product.

Table 6.1. demonstrates how each characteristic contributes to the success of the NPD process. We set three impact levels of each characteristic at different stages of the NPD. We judged the impact of certain personal characteristics as *high* (green highlighted fields) when the average score was between four and five inclusive of both values; *moderate* (blue highlighted fields) when the average score was between three and four inclusive of both values; *low* (no highlight) below the score of three.

Table 6.1. Impacts of lead users' personal characteristics on different stages of the NPD

	IMPACT on the technical success						IMPACT on the market success						IMPACT on the idea generation and concept formulation stage						IMPACT on the product development stage						IMPACT on the prototype testing stage						IMPACT on the market diffusion stage					
	Firm						Firm						Firm						Firm						Firm						Firm					
Characteristics / scores by firms and average	A	B	C	D	E	*AVG*	A	B	C	D	E	*AVG*	A	B	C	D	E	*AVG*	A	B	C	D	E	*AVG*	A	B	C	D	E	*AVG*	A	B	C	D	E	*AVG*
Expert level of professional knowledge	5	1	5	4	5	*4*	5	5	5	3	3	*4,2*	5	5	5	5	4	*4,8*	4	1	4	2	3	*2,8*	4	5	5	4	4	*4,4*	5	5	5	4	2	*4,2*
High level technical knowledge	4	1	2	4	4	*3*	5	5	2	2	3	*3,2*	3	2	3	4	4	*3,2*	4	1	2	2	3	*2,4*	4	5	4	5	4	*4,3*	5	5	2	3	2	*3,4*
Experimenter mindset	4	3	4	5	4	*4*	3	1	5	3	4	*3,2*	4	5	5	5	3	*4,4*	4	1	3	3	4	*3*	4	5	5	3	4	*4,2*	5	1	5	1	1	*2,6*
Social and professional connectedness	4	1	2	4	5	*3,2*	5	1	5	4	4	*3,7*	4	3	4	4	5	*4*	4	1	2	3	4	*2,8*	4	1	2	3	4	*2,7*	5	2	5	4	4	*4*
Formal authority	5	4	1	2	1	*2,6*	5	5	5	4	4	*4,6*	5	1	3	3	1	*2,6*	5	1	1	2	2	*2,1*	5	3	1	4	1	*2,8*	5	5	5	5	4	*4,8*
Collaboration attitude and communications skills	5	5	3	3	4	*3,9*	5	5	5	4	4	*4,6*	5	5	5	4	4	*4,5*	5	5	2	2	4	*3,5*	5	5	5	3	4	*4,4*	5	5	5	4	5	*4,8*

Source: own compilation

Our findings indicated a further novel insight as we found that there is no difference in the impact of the characteristics at different product complexities. It means that all characteristics of lead users are essential to achieve the success of the NPD in the case of low as well as high-complexity products.

In order to ease the selection of proper lead users, we identified signals (Table 5.3.) that enable innovation managers to apply our research results in their practice. We avoided applying unmeasurable signals like "tacit knowledge", "creativity" or "imagination capability" etc. which are not tangible, non-measurable and thus have no managerial implications. All signals shall be taken into consideration as a set of elements during the initial discussion with lead users.

6.3. Linking new knowledge to existing knowledge

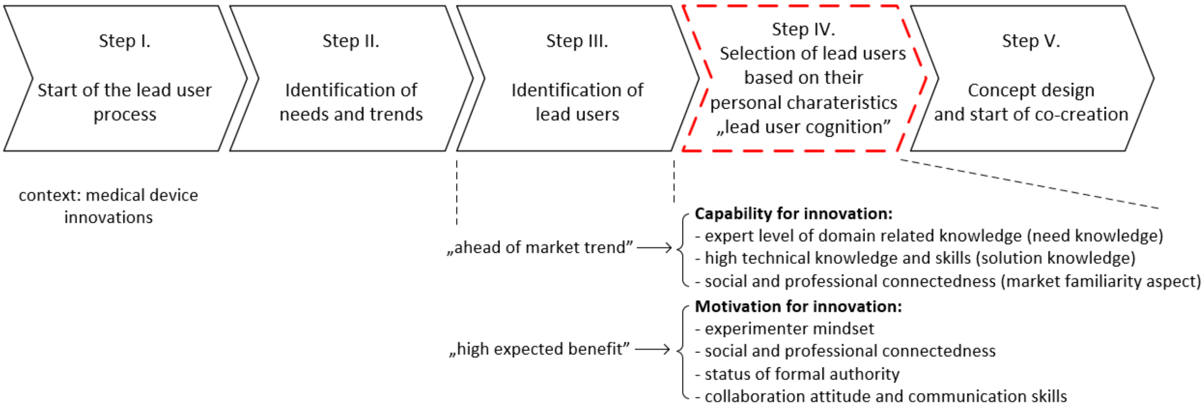
In order to answer the RQ3 we proposed a different approach to identify and select proper lead users for co-creation by employing the following line of argumentation. According to Pham, Lee and Stephen (2012), the intuitive feelings of experts are better able to predict future market trends. Moreover, Hogarth (2005) states that the intuitive form of judgment outperforms the analytical processes where the analytical complexity is high, and where it is difficult to identify any single formal rule that has high predictive validity. Furthermore, individuals with expert-level knowledge will more likely to discover an innovation opportunity than others (Shane, 2000).

Consequently, we state that lead users with 1. expert level of domain-related knowledge (need knowledge) and 2. high-level technical knowledge (solution knowledge), and 3. market familiarity (derived from social and professional connectedness) are better able to predict market trends than traditional trend assessment methods or internal/external market researchers (Figure 3.2.).

The second general characteristic of lead users is the “high expected benefit” which refers to the benefit by obtaining the solution (von Hippel, 1986). The expected benefit triggers users’ motivation to develop early prototypes and perform cycles of experimentation. The tacit-to-tacit conversion of solution knowledge assumes a high level of willingness to collaborate with product engineers (learning by doing), while the explicit-to-explicit knowledge conversion requires personal effort to share ideas informally through personal discussions and storytelling (Collins, 2001). The status of formal authority and social and professional connectedness might be considered as a facilitator in the process of obtaining high expected benefits. Based on the above line of reasoning we conclude that the high expected benefit of lead users might be associated with their personal characteristics including 1. experimenter mindset, 2. social and professional connectedness, 3. status of formal authority, 4. collaboration attitude and communications skills (Figure 3.2.).

In order to increase the efficiency of the lead user concept, we elaborated the method by adapting the “lead user cognition” partial method in the context of medical device innovations and integrated our findings in the selection phases of the partial method and linked the characteristics to the general attributes of lead users as “ahead of market trends” and “high expected benefit”.

Figure 6.2. Elaboration of the lead user method in the context of medical device innovations



Source: own compilation

In summary, properly selected lead users fulfil both requirements of “ahead of market trends” and fulfilling their “high expected benefit” through their identified personal characteristic elements shown in Figure 6.2. We note that the identified elements shall be considered in the dedicated context of medical device innovations.

6.4. Key results (theses) of the Dissertation

The key results of the dissertation are summarized in the following points. The key results (theses) of the Dissertation are considered as the overall conclusion of the Dissertation and also the corresponding answers to each research question (RQ1-RQ4).

Key results:

The overall conclusion of the Dissertation is described in the first and second points, while the main findings related to each research question are summarized afterwards in points 4, 5 and 6.

1. **The personal characteristics of lead users have an impact on the technical and market success of the co-created NPD process therefore they shall be considered during the selection process of lead users for the co-created NPD.**
2. **As the lead user method does not consider the personal characteristics of lead users in the identification process, the “*lead user cognition method*” aims to resolve this weakness by proposing a partial method which is embedded as an additional step in the lead user method. The *lead user cognition method* refers to the cognition process of the decision maker during the selection process of appropriate lead users for the co-created NPD process.**

As the lead user cognition method shall be interpreted in a dedicated context, the results of the second paper (the characteristic set of an appropriate lead user) shall be understood in the context of medical device innovations.

3. **Diverse characteristics are required at different stages of the co-created NDP and the required characteristics vary in the consumer and industrial context.**

The key result No. 3 answers RQ1 as *"What lead users' personal characteristics should be accounted by a decision maker in the selection process of lead users by considering each stage of the NPD process and the differences between the consumer and industrial segments?"* The identified characteristic elements are demonstrated in Figure 4.4. and Table 4.7. and the differences between the industrial and consumer segments are shown in Table 4.8. The systematic literature review through the resulting 45 primary studies provided a great overview of the required personal characteristics elements at different phases of the NPD and the results also emphasized that firms involve lead users mainly in the ideation phase of the NPD.

4. **Lead users must be involved in each stage of the co-created NPD process regardless of the complexity of the new products.**

The key result of No. 2 answers RQ2 as *"How comprehensively does a lead user need to be involved in the co-created NPD process?"* The findings are shown in Table 6.2. which belongs to the results of the second research paper.

5. **Each of the identified six personal characteristics of lead users makes a diverse impact at different stages of the co-created NPD in the process of reaching the technical and market success of the new product.**

The above key result answers RQ3 as *"How do the different personal characteristics of lead users impact the success of the NPD?"* The identified characteristics are discussed in the second research paper and the results are shown in Figure 5.1. The results are crucial for decision-makers to consider the intensity of lead user involvement in the NPD.

6. **The first general attribute of "ahead of market trend" can be determined by the following characteristics elements of lead users 1. expert level of domain-related knowledge (need knowledge), 2. high-level technical knowledge (solution knowledge), 3. market familiarity (derived from social and professional connectedness). These elements make lead users capable of being "ahead of market trend" and demonstrate their *capability for innovation*.**

The second general attribute of "high expected benefit" can be determined by characteristic elements of 1. experimenter mindset, 2. social and professional connectedness, 3. status of formal authority, and 4. collaboration attitude and communications skills. These elements demonstrate lead users' "high expected benefit" and demonstrate their *motivation for innovation.*

The key results No. 4 and No. 5 answer RQ4 as *"How can the identified personal elements be linked to the general characteristics of lead users as "ahead of market trend" and "high expected benefit"?"* The reference between the original two attributes and the identified characteristics demonstrates how the new knowledge (research results) advances the existing knowledge (lead user concept and method).

6.5. Limitations and future research

Our study is subject to limitations that might impact the research findings. In our case study, we employed a qualitative research method. We have not examined the case when multiple lead users participate in the NPD process as it sets up a different situation and might require other or additional characteristics elements from the participants. Another limitation is that we performed our investigation in the dedicated context of medical device innovations. In our research, we examined the selection problem from the perspective of the innovation manager.

Further research might apply quantitative research methods and other approaches in order to confirm our findings. The investigation of multiple lead users in the same lead users involved in NDP might open new research opportunities. The different contexts might require a different set of personal characteristics, which proposes an interesting future research agenda. Further research might examine the perspective of lead users by answering the question: how to select an appropriate firm for co-created NPD?

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