The role of context in science fiction prototyping: The digital industrial revolution

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Fabcreating, a highly sophisticated form of 3D printing, has become ubiquitous by 2033. We outline how digital fabrication might evolve in a science fiction prototype (SFP) and provide a 2033 use case in which consumers produce their own highly customized consumer electronics at home. It shows how consumers virtually select, customize and print mobile phones and highlights how digital fabrication impacts society at large. Our technology outlook is backed by expert interviews. Our story vignette forms a showcase to address the role of technology, creativity and context in SFP. We address the anatomy of SFP and argue that context is important in order to promote opportunity recognition and to envisage game changing technologies and their societal impact. We develop a SFP typology based on a technology prototype and context prototype perspective.

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1. Introduction

In our futuristic story vignette in 2033, consumer electronics (CE), an industry once dominated by large multinationals, is characterized by countless players in the market. Fabcreating, an extension of 3D printing and printed electronics, has propelled the digital industrial revolution substantially. Products can now be directly custom-designed without having to undergo time-intensive and expensive prototyping [1]. Home fabcreation fundamentally changes how we approach, design, buy and produce, and how we interact as a society at large. Our story vignette is about how mobile phones will be ordered and customized in virtual stores and printed at home. But what will the future in consumer technology be like by 2033, how will we buy our products and what about production processes?

One may suggest that globalization, technological change and turmoil on the financial markets lead to an increasing level of dynamism that decreases predictability of future developments considerably. According to Mehrmann [2], a defining nature of the market environment for consumer technology is rapid change paired with an exponentially decreasing time to deliver new technologies to market. This goes hand in hand with shortening technology life cycles. Spreng and Grady [3] outline how mobile devices have evolved from early analog models in 1983 to mobile computing devices. Smartphones integrate touch screen, broadband access, camera, video functionality, GPS, high computing power and a seemingly endless amount of applications and serve as an example of a constantly changing environment in consumer technology [3]. Formulating strategy, retaining competitive advantage and innovating in this environment are highly challenging endeavors. Experts largely agree[1] that digital fabrication technology will allow to deliver new applications beyond customer expectations. But can we predict future technology and how consumers and society at large will interact with it?

[1] Based on a survey conducted in the FP7 project “Diginova - Innovation for Digital Fabrication”, Grant agreement no.: 290559.
Technology forecasting is an established practice to serve this need [4]. According to Martino [4] modeling has become the most widely employed technique by the end of the 1970s. Today, there are models for effective information analysis and forecasting based on publications and patent information (e.g., [5]) and due to advances in computing, models have grown increasingly complex. Expert-driven qualitative methods such as the Delphi method, scenario analysis or mind mapping got developed over decades (for a detailed review please refer to [6]). Some recent approaches are of a very integrative nature. For instance Tseng et al. [7] propose a four-stage method that combines conjoint analysis, scenario analysis, the Delphi method, and the innovative diffusion model in order to forecast TV display technology adoption in Taiwan. It is crucial to understand consumers’ needs and to include expert opinion when analyzing new technology developments [7]. Most conventional techniques to anticipate the future are centered on algorithms forecasting events and analyses resting on a quantification of outcomes based on historic information or current trends which do not reach into the future. One of the major challenges in engineering research, design and associated fields lies in starting to build today what will be feasible several product cycles in the future. Futures research is thus increasingly gaining in relevance and also, from a scholarly perspective, in legitimacy [8].

An additional method to established forecasting practice that has recently gained substantial momentum is science fiction prototype (SFP) [9, 10, 8, 11]. In order to support product innovation at Intel, futurist Johnson [12] has introduced SFP, which has a high potential of mitigating several shortcomings (e.g., still sticking with the past context looking into the future) of established forecasting practice. SFP leads to future scenarios in story vignettes (in the form of e.g., short stories, videos, theater plays, comics) and is increasingly employed and established as a method in futures research ([9, 10, 8, 11]). Whereas physical prototyping has become a common tool in foreseeing what is feasible in terms of tangible opportunities [13–15], SFP is surprisingly still under-represented. SFPs are conceptual instead of physical [8]. In a large survey-based study Carleton and Cockayne [15] reveal that (physical) prototyping is conducted only in the later stages of the corporate innovation process. So why do organizations omit the obvious advantages associated with prototyping in the beginning of this process during opportunity recognition? We support recent developments in the SFP field by claiming that this methodology is an adequate tool for corporate innovation processes at the fuzzy front end [16]. It deserves more attention due to its high potential in helping future technology to advance, to foster technology transfer and to anticipate future contexts and social interaction (see e.g., [17, 9]). The underlying goal of SFP is to present new perspectives on a technology that can actually feed into its real development [18, 12]. Thus, it can provide specific scenarios and illuminate both benefits and pitfalls before they actually occur and can overcome several limitations of quantified trend and future analyses that rest on data from the past.

Wu [9, p.2] introduces an innovation triangle (Fig. 1), which “depicts how an SFP is formed by motivating technology, imagination, and creativity to achieve innovation, which stimulates entrepreneurship to create new ventures” and was developed to improve imagination workshops. We argue that these dimensions are highly relevant but an additional dimension, future context is needed. Only when one or more future technologies intersect with creativity and the relevant future environmental and societal context, can we derive the highest value from SFP (Fig. 2). This is what we will later define as a radical SFP that then fosters opportunity recognition, entrepreneurship, innovation and new venture creation in an optimal combination.

At hand of a highly transformative technology, we will use SFP as a method. We will outline the establishment of a paradigm shifting radical technological change and envision a potential use case in 2033 affecting society in an interlinked story vignette that stresses the importance of future context. The implications derived from the SFP lead us to a suggested framework that addresses how context is decisive in developing future technologies for future environments. Our underlying goal and third objective is to further advance SFP as a scientific method by enriching it with a proposed typology and linking it as a source of creative inspiration and creative visioning to entrepreneurship and innovation. We advocate SFP as a powerful tool to facilitate opportunity recognition. A shortcoming of most research on entrepreneurship is that it starts investigating the process after opportunities have already been discovered [19].

Fig. 1. The innovation triangle: three components of technology-based innovation and entrepreneurship are creativity, imagination and technology. Note: illustration according to Wu [9, p.2].

Fig. 2. A lens for SFP. Note: the gray shaded area represents the optimal constellation for high-impact radical SFP. Only in this constellation there is a match of future technology, creativity and relevant context.
2. Technological background & context of the story vignette

Most products in consumer technology result from an established mass production infrastructure. This production infrastructure rests upon extensive prototyping and testing before a product is mass-produced. Customization is usually modular and scale economies form an important driver of cost-efficient production. A cell phone for example has to pass several modular steps in the value chain before it reaches the end-customer\(^1\) [20]. From a business perspective, this component approach involves drawbacks like large stocks, high manual labor, large capital investments, and long distance transportation. Whereas in the 1990s the industry was still vertically integrated, it is becoming increasingly horizontal [20]. Emerging customer-needs like customization, personalization, or on-demand fulfillment cannot be properly addressed through mass production infrastructure. A trend towards more customization in an increasingly digital and networked setting calls for a paradigm shift in manufacturing.

Digital fabrication is commonly referred to as the third industrial revolution [21–23]. Digital designs are directly converted into ready-to-use products skipping the prototyping step. From the beginning, this revolution is not limited to large firms but of a highly consumer-involving nature. Thus, consumers are merely prosumers who produce and consume. 3D printing can be described as a radical innovation, as it will disrupt the current manufacturing industry: new market entrants with new products, services, and business models substantially challenge the established players\(^2\) [24]. In the subsequent section, the state of technology will be further analyzed based on the results of a recent expert survey that has been conducted with digital fabrication experts in the context of the FP7 project “Diginova - Innovation for Digital Fabrication”.\(^4\)

Our SFP blends an advanced version of 3D printing and printed electronics with a futuristic environment. The story describes the potential development process of the technology shift. An embedded story vignette describes a potential use case in 2033 and how users interact with consumer technology enabled by digital fabrication. It demonstrates how virtual reality and reality become increasingly intertwined and how most products can be fabcreated at the consumer premises. Consumers reach the highest degree of customization by printing perfectly tailored online goods at home.

2.1. Digital fabrication — the state of technology in 2013

“Digital fabrication will be the next industrial revolution — no doubt!” (CEO of a leading manufacturer)

In order to obtain a better sense of the current technological landscape in digital fabrication, the FP7 Diginova consortium has conducted an expert survey among leading industry experts (sample characteristics depicted in Appendix A.1). Indeed, the statement that digital fabrication will fundamentally change the world we live in is agreed upon by 68% of the experts (out of which 24% strongly agreed) and in addition, 27% anticipated partial but yet significant changes. Only 4% disagreed with the statement. Following an emerging technology hype-cycle, digital fabrication is a promising technology in a nascent stage (56%) and 37% of respondents perceive digital fabrication being currently at the peak of inflated expectations. It allows for “batch size one, change over time zero and configuration flexibility to adopt easily to new products”. Considering the strength of the organizations that the experts surveyed work for, it is important to note that technological advances and R&D competencies are considered as major organizational strengths (Fig. 3). The technology, though additive manufacturing and 3D printing date back to the early 1980s, is still in R&D stage. Strengths in detecting new market trends, leveraging resources and adaptability to production to market needs are still under-represented. Out of 42 experts, 88% either strongly agree or agree that improved material properties are required for business enhancing development and 87% regard a wider choice of materials as business enhancing. Accordingly, materials are still bottleneck to this emerging technology.

An integral part of the survey is an assessment of future applications and a respective years to market evaluation. This expert outlook is provided in Fig. 4, which also addresses several other potential use cases in consumer technology. In our SFP, we further elaborate on the role of digital fabrication in consumer technology at the example of printing a complete highly customized cell phone. One of the base technologies embedded in this SFP, printable displays, is represented in Fig. 3.

In summary, as a survey participant stated, digital fabrication allows for a “completely distributed manufacturing system incorporating the cost benefits associated with production line manufacturing combined with bespoke products and solutions”. Electronics have already been printed for years (e.g. [25]) and almost all kinds of materials can be employed at high precision rates. A combination of electronics, printing and additive manufacturing appears to be fruitful in the future [26]. Industry experts have high expectations regarding its production paradigm shifting potential. Bespoke manufacturing at point of use will enable “value to be secured by the originators of the

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\(^1\) Generic hardware and software components have to be developed
\(^2\) Specific components like the operating system have to be programmed to integrate the generic components and make them work
\(^3\) The end-user device is specified through design & integration
\(^4\) The product has to be physically assembled, produced and branded, before it reaches the customer.

\(^4\) Sample characteristics and background to the survey in Appendix A.
time to market <10 years
- biomedical diagnostics in <5 years 63% 96%
- sensing, track & trace in <5 years 70% 92%
- disposable electronics in <5 years 51% 92%
- lighting in <5 years 51% 90%
- smart paper, printed intelligence in <5 years 51%

Fig. 4. When will products based on digital fabrication be on the market for the first time? Note: Multiple answers possible, n varies between 38 and 41; the cut off point for a technology to be considered is a cumulated agreement of 90% or more to be considered mature in the respective time frame. Source: the FP7 project "Diginova - Innovation for Digital Fabrication".

2.2. The world in 2033 – the future context

In 2033 almost everything is printed or fabcreated, as we name the process. Back in 2013, printing was a routine that we performed at our offices and considered an old-fashioned commodity. Now, it dominates our daily lives. The first 3D printers were called Fabbers (short for Digital Fabricators) but fabcreating is more a composite of fab for fabulous and creation regarding its etymology. Whereas the internet has revolutionized how we access, create, process and store information and how we interact and interconnect with other people, Fabcreation has revolutionized manufacturing. Advances in 3D printing have revolutionized the entire consumer technology landscape, how business is conducted and the way we live as a society in 2033.

Fabcreation enables local manufacturing down to the level of individual desktop users at home: end user objects that are one of a kind can be created. Physical objects can be immediately delivered to home user desktops via virtual shopping centers. Production in bulk and holding products in stock have become largely obsolete, as they are based on an outdated production concept. What we can observe is a highly individualized production and the highest degree of customization. Small businesses, homes and even schools have become centers of new product design and locations for production. People engage in co-creation to craft their highly customized product and a multitude of small businesses has emerged. Virtual repositories provide an endless amount of source code for product designs. A common ground to start from is the underlying design and programming language Fabicon that has even been installed as a mandatory subject at elementary schools by the beginning of 2029. So almost everybody is capable of designing and fabcreating individualized products. Consumers are printing food, objects of all kind and complete ready-to-use devices in consumer technology. A major breakthrough in bio-technology has been printing fully functional vitals for transplantation. There is no boundary in terms of an industry in which Fabcreation has not revolutionized businesses and the corresponding business models. It is a process revolution affecting the way society lives and evolves. Consumer technology has become highly driven by entrepreneurs and small companies. Instead of assembling CE from a multitude of separate parts, it is fabcreated at consumers’ premises at one piece in a single machine. The core competency now lies in producing the best source code creating the most customized and functional devices for end consumers. A fabcreator is installed in almost every household. The adoption curve highly resembles the e-mail adoption curve at the dawn of the 21st century. A connection to e-mail is not far-fetched, as fabcreators are the enabling technology of e-object.

3. Story vignette

In this section, we will propose a framework outlining how context is taken into account in SFP and hint at the process of fiction transformation. With an exponential adoption curve of fabcreators in households, the possibilities this technology enables sky rocket. It all starts with innovative base technology revolutionizing production processes significantly. The potential use case in the story vignette shows how fabcreation enables end users to print their own devices. Features, designs, and other product specifications are downloaded from a virtual component store and afterwards directly merged and fabcreated. Competition is high but so are opportunities. Except for skill and creativity, barriers to entry are quasi non-existent. Production has become a social event. Social production is widespread, as going virtual has become the gate to the world and the fabcreator is the key to consumption. Virtual show rooms and stores are easily accessible, as TVs and computers have long been completely integrated into a fully virtually real (VR) environment. VR is three dimensional in space and voice, motion and emotion-controlled. While back 20 years ago earlier generation printers took several hours to fabcreate products and resolution was poor, production time has now reduced significantly at a remarkably high resolution. This enables a multitude of applications.

3.1. Ann, Brian and digital fabrication

It is October 2012, Brian is sitting in his student dorm watching TV. It has been a tough day with lectures on entrepreneurial theory in the morning followed by an applied afternoon session on creativity. A representative from a nearby research institute introduced the students to
the current state of research in printed electronics and associated patents and highlighted how they struggle with transforming their newest findings into marketable products. What is more, they learned about a new method in class: science fiction prototyping. Now, the students have to come up with a future application of digital fabrication in 20 years ahead. There were so many ideas in the room. But what are the game changing technologies of the future? Switching through the channels, Brian comes across an old Star Trek series from 1987: “Star Trek: The Next Generation”. The episode first employs what is referred to as the “replicator”. Brian is fascinated by the device. He keeps on watching and flips through several social network messages on his smartphone. He is messaging with Ann, one of his friends and team colleagues in creativity class.

B: Ann, switch to Channel 10... they are airing this old Star Trek series.

He wants to know more about the replicator and punches the term into the search interface on his phone. He instantly obtains a result: “a device that can produce any non-living matter that it has on file”. Brian considers the replicator as being a funny idea but regards it as pure science fiction. When he sees the subsequent episode in which communicator badges are used, he is stunned and thrilled:

B: Wait a minute! — He looks at his new blue tooth in-ear device. This is not just science fiction.

B: Ann, have you seen the communicator badges? They’ve already had them before phones were even popular or designed the way they are. Do you think there’s a technology like the replicator in place as well?

A: I’ve recently read an article on digital manufacturing in The Economist! It proclaims a third industrial revolution triggered by manufacturing going digital.

Brian reads the suggested article. He learns that additive manufacturing and 3D printing are strongly associated with this development and form the base technologies that are forecast to revolutionize manufacturing, associated business models and location strategies. Some days later, Brian meets Ann in the dining hall to discuss a potential topic for their creativity class.

B: I’m still so fascinated by our findings on 3D printing.

A: For me it’s more the printed electronics part. It’s just amazing. You could create displays that are like paper... Brian is constantly busy with his phone and seemingly mentally absent.

A: Come on Brian, stop it. We want to brainstorm ideas. I’ve got another meeting in an hour.

B: Let’s start a project based on this technology.

A: Which technology?

B: You think one could print them?

A: What do you mean?

B: Cell phones. They’ve got lots of electronics.

A: And displays! Sounds interesting. But I guess we won’t need them anymore in 2033?

B: You mean that’s not the way we’re going to communicate in the future and smart phones are going to be replaced?

A: Exactly. Who knows. There is happening so much in technology.

They decide to conduct profound due diligence on the current state of digital fabrication. Brian, an engineer, volunteers to focus on the technology part while Ann, a business major with passion for design, will screen all aspects related to product design and future trends associated with the usability of smart phones and possible alternatives.

B: There are so many 3D printers out there, it’s unbelievable. You can find them in all kinds of sizes, ranging from industry to desktop applications. And this is apparently just the beginning, Ann, this has the potential to change how we design, produce, and buy stuff!

Ann can immediately see that this class project is going to be fun. Brian continues:

B: Already in additive manufacturing today... just by putting layer on layer of specific materials... one can print pretty much anything. Entire engines. Even first houses got printed! Guess what: The form does not matter and forget about prototyping. It’s all happening in CAD, can be visualized on screen and there you go!

The degree of detail of his technology knowledge after just one week of research is remarkable. Ann joins in by adding.

B: I came across similar articles, especially a combination of printing electronics and additive manufacturing appears to be interesting. Even at the company my Dad works for.

Ann is critical. She considers all the articles that Brian has discovered in the popular press as overly enthusiastic.

A: Brian, tell me, if 3D printing was so great, why hasn’t it been adopted yet?

She issues her concerns.

A: I mean, come on, have you ever come across this before? It strikes me that such a sophisticated technology does not find a better solution to integrate design and production.

Throughout the term, both work harder for this project than for any other class. They talk to experts in the field and engage in creative thinking on how this radical technology will unfold its impact in the upcoming decades.
B: Listen Ann, traditional printer manufacturers are starting to gain interest in producing home printer series capable of 3D printing. But they are still at a very basic level.

By now, their project is not about developing an individual product application as initially planned. It is more about grasping 3D printing, printed electronics and understanding its future potential and how society will interact with it.

It is Monday, December 10th. Final project presentations are due.

A: Nervous?

B: We’re well-prepared. Let’s go!

The creativity class has a tradition to invite executives from large corporations, investors and industry experts as judges for the student projects. The room is crowded, as the presentations are famous for their innovative character. They start with a couple of slides on the current state of technology followed by a story vignette on how digital fabrication will change our everyday life with excerpts from the following SFP they wrote.

3.2. The project: use case 2033 — Shelly is printing her new phone

It is 8 pm. Shelly (S) has prepared dinner for her friends Cindy (C) and Betty (B) and they are planning to spend a night out later that evening. It is for the 5th time that they are celebrating their final graduation from the university. Shelly is in a bad mood — she has lost her phone bracelet on her jogging route and it is not traceable. It is fully shock-proof, waterproof and would have run another 4 weeks on the power unit. She tells her friends. As the phone is based on Shelly’s biometrics, nobody except for her can use it. This is what makes her mad. She sighs:

S: Someone must have removed the power unit so that I cannot trace it back. This is so useless! Luckily, no data are lost. Damage is reduced to replacing the device.

B: You already know, which new base model to pick and which new functionalities and features there are?

S: Absolutely not. There is so much happening in consumer electronics. I lost track of the latest trends.

C: Let’s help you. I’ve just designed and fabcreated my new phone bracelet last week.

Just like in many other industries, such as the food industry, fabcreation has led to fundamental changes. As most products are home-fabcreated (except for bigger devices that are fabcreated at printing hubs in the vicinity), they can be ordered and self-designed in virtual show rooms and immediately produced ready for use at home. Shelly and her guests move to the living room after dinner. Sitting on the couch and enjoying their drinks, she distributes 3D lenses to go virtual. Augmented reality virtualizing, blending virtual reality directly into the vision of the human eye by manipulating the brain, has not been adopted yet. Substantial law suits have followed a failed prototype test. Nevertheless, the lenses provide a reasonably close experience in VR. Customers can move around in virtual stores and switch from one showroom to another at ease. It is a platform on which all designers for fabcreated goods offer their latest work. All products that are available online can be accessed and what you see as a virtual product is a visualized source code.

S: Let’s enter the virtual store!

S: Log into “Reunion52033Shelly”.

Each user needs an account to avoid fraud. Via unique profiles that have to be verified with legal identification documents, virtual stores know their customers, their habits, their online social network activities, their in-store behavior and, of course, all their preferences. Users get tailored recommendations and obtain the highest degree of customization: Products can be edited according to individual preferences and the result is immediately observable. Selecting a product of choice offers a multitude of features to choose from. Every option desired in CE, such as where buttons should be located and which form a device should ideally have, can be perfectly harmonized. Shelly and her friends start designing the phone bracelet.

B: So, what are your preferences?

S: It has to be ultra thin and highly flexible — I always listen to lots of music while doing sports.

C: What about this template?

S: It looks great but I want the display to be expendable to watch movies while travelling — and it has to be perfectly adjusted to my wrist

Betty redesigns in a flash.

S: Please, could you make it a bit more fancy in terms of design?

Design packages immediately pop up and can be directly applied to the customized model. Complementary products are directly offered and presented. The world of virtual commerce is endless. The product offerings are based on what people being interested in the particular phone have bought.

B: Look at this! There are new visualization lenses including street social networking, navigational system and video conferencing mode.

The lenses have definitely entered the shopping cart. It takes a while to add biometric data as a fraud protection to both devices. While Shelly and Betty are still discussing the design of the phone bracelet and keep on introducing new modifications to several base models, Cindy feels like being of no help.
C: Would you mind me designing a new necklace in the meanwhile?

She starts playing around with a couple of designs in the virtual store that fit her new dress that she bought for their reunion. In the virtual store all product categories are just a step into another virtual room away. What is more, there are suggestions in terms of what would match her individual style and the dress. Cindy has modified a necklace in terms of color and material. It is now a combination of tiny sea shells with golden elements connected by a fine line made of silver.

C: Perfect! Estimated fabcreation time <15 min.!

She puts the design into her shopping cart and is looking forward to the fabcreated result. She joins Shelly and Betty. They have come to a conclusion on the best phone bracelet.

C: Finally!

S: With these new lenses I can go virtual from anywhere! You like the design of the bracelet by the way?

In order not to be impolite, Cindy reshapes the bracelet a little bit in the editing mode. Cindy presents her new necklace.

B: Wow! This is so beautiful! Now you're all set for tonight!

Then Shelly has an idea.

S: Why not surprise Maria? The necklace is just beautiful!

They make it a special memory of the reunion, finish the design together and then send to Maria so she can fabcreate it after work. The girls fabcreate almost everything they purchase. They strongly appreciate the convenience to shop almost anything anytime and anywhere. Fabcreating has become part of their culture just like going virtual. And especially in CE, it is very handy to see the device in its full functionality being virtual, while still being able to customize to individual needs. However, there is one product group they would rather not fabcreate: Fashion. When Cindy presents her necklace in the virtual shopping mall, she instantly gets a dress recommendation. Each purchasing transaction or search history and taste is reflected in her account and the system knows what looks fit her best according to online social networks she is engaged in and the feedback she receives on pictures.

S: Hmm...the look is there but going virtual still cannot simulate odors and feel. I'm for the real boutiques in town and having coffee at a bar when moving from store to store.

The recommendation is a perfect match with her taste and just for fun she puts on the dress in a virtual fitting room. Her friends are really excited about it but have their strong principles on shopping fashion. Fabcreated cloth, especially with higher quality material, just does not convey the proper feeling. At least this is what many fashion lovers report. Consumer technology is the bridge between humans and VR, it forms the interfaces and input devices.

After having exited the virtual world and bought the source code, it is now just a matter of having the raw materials required and time. Fabcreators are true all-rounders but highly dependent on the proper resource mix. The resource requirements are attached to each product (or job when an e-object is coming in). The resource requirements communicate with the printer and if not available and upon confirmation by the users new resources are ordered in either dedicated size batches or defined size batches to keep a repository.

B: Did any of you keep track of the resources we need?

S: Good point. I guess not.

Having to order resources via the replenish button causes some production delays, till resources are delivered. For urgent production needs, there are 24/7 local service centers that sell and deliver raw material cartridges according to requested specifications. Replenishment is fairly easy and consists of adding powder and/or new cartridges. They start fabcreating their purchases by checking out. The fabcreating lasts about 40 min. for the phone bracelet and yet another 15 min. for each accessory bracelet. While already printing for 10 min., a warning pops up.

S: Here we go...noble earth constraint: error code “VIIb/6”. Now I need to re-order.

B: No way. Just try the proceed without button.

S: Proceed without?

B: It’s a new function in the 4th generation printers. Usually, if there are resource constraints, there is a work-around in the programming code at a surcharge that optimizes accordingly.

S: Ah, I see. 10 EUR on top and all products can be completed on time. Let’s go for it.

Fabcreators ensure a highly efficient use of resources as remaining raw material powder is directly withdrawn by suction, separated, restored and then refilled into the proper raw material container. While the fabcreator is printing their products, the girls send an e-object to Maria’s desktop. It is a supplement to the necklace: Their university mascot holding a card with their best wishes. Sending goods while being virtual is controversial discussions in the media about e-object since its...
increasing adoption in 2025. Whereas transportation of goods via planes, ship, railway and trucks has been minimized so that supply chains are almost carbon dioxide neutral, there is still a duplication problem. Sending an e-object with a fab-scanner always constitutes the fabcreation of a duplicate. Also, copyright issues are a prevailing problem: 20 years ago it was almost impossible to copy consumer electronics completely. Nowadays, one only needs access to the digital source code of a product.

Finally, all fabcreating jobs have been completed and the girls head out to town to spend a great night out.

3.3. Technology transformation

The audience applauds. The jury is overwhelmed by their story and its potential. A research institute representative (R) directly approaches Ann and Brian during a get-together subsequent to their presentation.

R: Very well-done, I'm also very impressed by your understanding of the technologies embedded. We have a spin-off company at the moment. Would you like to help us out with the market analyses and the business plan?

Ann and Brian agree – this offer fits their practically-oriented master thesis proposal well.

Brian wakes up. It is cold, dark and he has been in this situation twice this week. Only 3 h of sleep. It is 6.30 am on the 23rd of November 2016. He must have run out of electricity and heating credit once again. His last prototype, 3Del, took all his savings and a first round of venture capital has also been fully allocated and spent.

B: How to pay the wages of my two employees next week?

Sleepless nights. At least his phone is still working. Brian checks his bank account.

B: Still nothing.

After graduating from the university and working for the research institute spin-off for two years subsequent to his final thesis, Brian decided to follow his passion: 3D printing. In the same year, at a leading technology conference in London, he met two like-minded graduates who shared his vision on the next generation of desktop 3D printers that can also print simple electronics. Brian had relocated to share an apartment with his colleagues. The team was hard working, spending day and night in their lab, and striving for a 3D printer with uncompromising precision. 3Del started as an attempt to unite the best features of all available 3D printers available by 2014 without violating any patent. Brian, the CEO of the start-up, decided to name the prototype 3Del (3D electronics). The first attempts were frustrating and somehow disillusioning, as durability of 3Del allowed a maximum of 5 music players being printed before it broke down. It took them so much effort to optimize the raw material ink allocation — a true bottleneck in printing CE.

Brian receives a message on his phone. One missed call.

S: Brian, this is John Smith. I've recently read a small article on your 3Del in a technology blog. It looks like you have come across something big with your printer material ink injection method. We should talk. We're really interested. Please call me back.

Smith (S) is a well-known blogger in the digital fabrication scene, former top manager at a large hardware manufacturer and now managing the corporate venture capital (CVC) fund of that manufacturer. Brian and Smith meet several times and the CVC allocates financial support for a 30% stake. Another 10 months and a total of USD 15 million in financing results in 3DelUltimate, a ready-to-use home fabcreator that is able to print three-dimensional products with electronic properties. From here on, market potential develops rapidly.

In 2019, installed base reaches more than 500,000 customers. 3Del keeps on revolutionizing the production landscape in a radical fashion. With Smith being involved in the management affairs due to the CVC engagement and putting in a lot of expertise from his industry, the parent company increasingly gains interest. Though being engaged in additive manufacturing and printed electronics, the leading hardware manufacturer had neglected the desktop segment that is now characterized by exponential growth. As founding member, Brian still holds a 30% stake in the company. Brian agrees to sell 3Del with him remaining in a board position for a very large undisclosed sum higher than USD 100 million. An interviewer (I) from a leading newspaper asks Brian about the deal and his motivation.

B: I'm not financially-oriented. I love creating the future. In my new startup, I want to create a ubiquitous programming language that is easy to use. I'm convinced that everybody will have a 3Del in the future and I want everybody to participate.

I: But electricity shut-downs will not be an issue anymore? Brian, given your expertise, what would be your market outlook?

B: Well, with base technology and standards being about to be established, world-wide prevalence of fabcreators is estimated to be between 20 and 30 million by 2023. In addition, market size for printed consumer electronics is estimated to reach 1 trillion by 2023.5 The technology is highly disruptive and transforms a multitude of markets. Intelligent paper, toys, electric tooth brushes, watches and of course audio players can be printed. This change in consumer technology enables totally new business models. New ventures are mushrooming everywhere. We can observe electronic commerce at its perfection.

I: The way you've founded 3Del and your way of thinking is so novel. What is more, you've gained a high reputation as a distinguished futurist and various leading magazines featured

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5 Although this figure is fictitious in the context of our story line, a report published by the McKinsey Global Institute estimates the sales of printed consumer products at $4 trillion by 2025. Source: Disruptive technologies: Advances that will transform life, business, and the global economy. McKinsey Global Institute, May 2013.
you as one of the technology visionaries of the decade. What’s the next big thing in technology?

B: First of all, it’s not me who founded 3Del. It wouldn’t have been possible without my co-founders Hannah and Matt. Secondly, it will be less about technology and more about how we interact with it. Social production will be huge. There will be a growing community of small vendors, when products can be distributed as source code and are increasingly produced at consumer premises. This will enable new business opportunities everywhere with a time to market of virtually zero. Design will increasingly evolve in online social networks instead of in design labs and new ideas can be implemented at a glance.

After graduation and 2 years in the spin-off company, Ann can now apply her design skills while satisfying her curiosity for new technologies. Her first position is in the user interface (UI) department that belongs to an online retailer. Ann is responsible for online customer usage patterns and her goal lies in developing the most convenient and user-friendly interface (UI) department that belongs to an online retailer. She has developed an excellent sense for what her customers desire and that virtual shopping journeys offer a lot of potential. In a board presentation she outlines:

A: Data strongly suggest that our customers want to be taken on a virtual shopping journey. They want to have the in-shop experience online.

She has prepared several slides.

A: How do you think our customers will buy 10 years from now?

Ann guides through several scenarios. Every team member can grasp her enthusiasm and passion for the topic.

A: Virtual reality is an emerging technology. Imagine customers will use the online world like a room they can walk into.

Ann outlines the technology, its capabilities, and her vision for the future of the online retail world.

A: Imagine now, they wouldn’t have to wait till their products are shipped but they can produce them at home.

She provides them with an updated version of the SFP she developed with Brian back in the entrepreneurship class and blends it with a clear connection to state of the art digital fabrication technology and virtual reality. She addresses the advances of a Los Angeles-based company projecting holograms into the living room.6 Robert, the vice president for sales, is convinced:

R: Wow, we expected you would present us some data analytics. This is impressive. I have never thought about online shopping this way. Virtual reality seems like opening up a lot of opportunities for us.

Robert encourages Ann to continue working on this idea and to try to mobilize more resources. Even Alexander, who is in charge of the entire online shopping system and a known critic of changes to the system, is highly interested. Over several months, the group works on fictional usage scenarios. Ann has picked up these skills in her entrepreneurship education at the university. The measures taken range from designing potential future user scenarios, test-buying in virtual stores and designing a mock-up online shop that allows a high degree of user participation in virtual shopping rooms. Within months, Ann’s project gains C-level attention. They come up with several implications in terms of how the online store can leverage VR to a maximum of futuristic user experience.

By 2022, Ann’s company has become the leading VR player in the market and traditional online shops play a subordinated role. Everybody in her firm is convinced that VR is revolutionizing e-commerce and the way we live. Ann’s team has tried to anticipate how society will interact in the upcoming decade and what are the most significant technological advancements. A rapid adoption of desktop 3D printers is one of these major advancements. Accordingly, all new shopping platforms plan on VR being the dominant way of shopping. To become the market leader in e-commerce, one has to take into account substantial risk these days. Ann is convinced that they have understood the context of future online interaction very well and are ahead of the curve.

4. Discussion and framework

4.1. Implications

At the beginning, 3D printers were a gadget for technology enthusiasts that used open source platforms to further develop functionality. Following our scenario, fabcreation has fundamentally revolutionized production and the way we live and interact as a society. What is more, the world as we depict it in 2033 with VR being the dominant way of how people shop and interact and e-object being around clearly shows how context matters. Going virtual has fundamentally changed how people shop and interact. Social production is a concept that would not work nowadays. A new method of production opens up an entirely new market in terms of customizable source code being traded instead of finalized products. What is more, it utilizes new sources of supply for raw materials. Last but not least, fabcreation as we envision it creates an entirely new order of industrial organization dominated by small firms and entrepreneurs as opposed to conglomerates. How Ann and Brian advance fabcreation in the story vignette connects to a possible vision of how SFP can lead to actual fiction transformation into real product or service prototypes. According to our understanding, context lies at the core of SFP to anticipate proper product design and technology needs for future settings. Being ahead of the curve cannot rest on past context and we will further explicate this line of thought in the following section and derive two resulting frameworks.

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6 ProVision (http://provision.tv).
4.2. Connection to entrepreneurship and creativity

Fabcreation is a radical innovation in Schumpeterian [27] terms: It forms significant improvement of digital fabrication. Fabcreating combines 3D printing technologies, additive manufac-
turing and printed electronics and we depict a science fiction product prototype. The development setting reveals how inspiration, creativity and entrepreneurship support SFP and also advance the actual implementation. This is in line with Wu [9], who makes a call for future research on how the SFP process from conceptual stage and creativity to business innovation works.

Closely related is Amabile’s [29] view on entrepreneurial creativity which is dependent on the social environment and can be supported by the social dimension of SFP. Following Amabile, the social environment of an entrepreneur is highly important to achieve entrepreneurial success. The important social dimension for entrepreneurs is the social network. However, some important characteristics of social networks have only recently begun to be researched. Thus, entrepreneurial creativity captures the “generation and implementation of novel, appropriate ideas to establish a new venture”. Uncertainty is not resolved by creativity due to a lack of certain calculable information to start from. Nevertheless, creativity has been elaborated on in terms of its role in handling ambiguity [30] and resolving conflicting interpretations of the environment. Thus, it helps to derive novel solutions in problem solving and can help anticipate problems before they occur. It helps to connect previously unconnected ideas and concepts and advocates freedom to think outside the boundaries of existent knowledge.

But how do entrepreneurs recognize and develop the opportunity to introduce such a radical and game changing technology as we present in our technology prototype? Shane and Venkataraman focus on opportunity recognition as a process. Shane [32] finds that technological change does not necessarily prompt that entrepreneurial opportunities are recognized right away. The pure existence of an entrepreneurial opportunity to obtain profit is thus insufficient. In order to earn entrepreneurial profit, an individual has to recognize that the opportunity exists and is valuable [31]. More explicitly, entrepreneurs have to discover opportunities in which the new technology can be exploited [32]. This strongly connects to SF prototypes and their context dimensions. The context dimension offers scenarios in which a current technology or advancement thereof is applied to a fictional setting and anticipates future needs and facing respective challenges.

Given our story vignette with its embedded use cases and according to our understanding of SFP, it is important to distinguish two types of prototype dimensions: science fiction technology prototypes and science fiction context prototypes. Only given that these two dimensions and their interaction are taken into account, we can obtain a radical SFP that can lead to fiction transformation into a highly transformative radical innovation. In the following, we will address the underlying power of our SFP according to these two dimensions and also refer to fiction transformation. Furthermore, we will suggest a typology of SFP.

4.3. Science fiction technology prototypes

A SF technology prototype is focusing on a current early stage science and technology, often in a very immature stage full of inflated expectations. Egerton et al. [33, p.1] state that “a Science Fiction prototype uses science fiction based explicitly on science fact as a design tool in the development of technology.” It tries to extrapolate potential application fields given current technology roadblocks have been solved. Thus, SFP facilitates long range product development [11]. The SF technology prototype thus looks beyond what is currently technologically feasible and creates use cases in which this technology can evolve. A SF technology prototype can constitute a product like in CE or a service. It thus prepares the ground for entrepreneurial thinking and opportunity recognition, and new product development and the exploration of new business models are enabled. In several ways, this is related to the first part of the corporate innovation process. This task requires high expertise in the respective technology field. Steve Jobs is often the first name that is associated with successful corporate and especially product visioning. His talent to come up with game changing devices and services is legendary. In 1997, at the Worldwide Developers Conference, Steve Jobs draws on an analogy of “the world he is living in” to share his vision on synchronization of information among different devices through a technology nowadays known as cloud computing. Remarkable is that cloud computing did not reach significant public attention or market entry before 2010.

According to Fig. 5 SFP has a product prototype focusing on technology at the core. The context dimension around it addresses contingencies and how society will interact with this technology in future possibility space. Context prototypes can also capture more than one technology prototype and the future possibility space captures the entire set of scenarios, which is endless and unknown by assumption. Accordingly, SFP will most likely approximate some reality and foster creative thinking while not being able to predict the future.

4.4. Science fiction context prototypes

Concerning SF context prototypes, we argue that the product world is more than ever interdependent on its environment and therefore we go one step further than technology. Technological standards have to be considered, customer demographics have to be observed carefully and radical technology changes have to be anticipated. Thus an emerging technology is highly dependent on how society interacts at large and how society interacts with it. The value of

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7 Interestingly, the technology studied in his research is early 3D printing.

8 Although we focus on products, services can be considered here in equal measure.
mobile phones is no longer evaluated by the product itself but also by the access to potential embedded services. In order to grasp all contingent aspects, one also has to facilitate interactions of the SF product prototype with its environment by envisioning an equally important SF context prototype. Even though context is hardly possible to be anticipated [11], according to Birtchnell and Urry [10], who refer to Urry [34], the use in policy and planning to address social aspects of future worlds has subsequently appeared in the literature. This requires thinking out of the box, engaging with other technology trends, or digging into social science data. Technology-driven organizations recognize the benefit of also elaborating the context dimensions of SF prototypes. Corporations like Intel apply social science research, ethnographic studies, and external industry knowledge to understand the customer–product interaction of the future [35]. The Siemens AG publishes the journal “Pictures of the Future” biannually. It is dedicated to share fictional context prototypes with all kinds of parties, including experts, employees, and customers.

Accordingly, there exists a variety of SF prototypes. Some focus on future product specifications while others elaborate more on the environment and its impact on the product context. Ideally, creative science prototypes stress the embeddedness of a product or service prototype within an environment prototype in a future possibility space.

4.5. Fiction transformation and why context matters

Our vignette around the year 2033 presents a possible story line about how fabcreation could become reality. What is more it hints at fiction transformation and how SFP can be used in creativity workshops at universities to foster inspiration towards real prototypes [9]. How we can use and leverage SFP to benefit the most from the technique in terms of real product development is an important question that is still calling for more research. In our story, Ann and Brian are the protagonists driving change.

It is important to understand that the prototype in SFP is not tangible and not an actual product we are building. It is merely an approximation of what we might be able to build. This notion is also picked up by Bell et al. [8, p.23], who argue that science fiction has “defining potential to become applied fiction” and stress the role of authors, critical observers and social commentators.

When organizations gradually try to transform a SF product prototype into science reality, they have several possibilities: First, they can keep the product prototype within its future context to engineer science reality for the to be developed use case and social context. Once the SF prototype is transformed, it turns into a real prototype (RP) still being designed for the future context. Within the future context and being leveraged to science reality, the product reveals a perfect fit and is in line with the prevailing context. This however requires the future context to be involved from the beginning onwards. Otherwise, there is a mismatch between product and context leading to the product/technology most likely not being accepted by future consumers. Let us take a look at tablet PCs as an example: In science fiction literature as early as 19519 and appearing in Stanley Kubrick’s 1968 film “2001: A Space Odyssey”, this technology has seen several iterations and attempts of fiction transformational development including for instance Apple’s 1987 tablet project [36], Microsoft’s Tablet PC in 2000 [37] and Intel’s Web Tablet [38]. Then, in 2010 the iPad hit the market [39]. We argue that the context and surrounding application landscapes were not suitable before 2010, ubiquitous internet access and cloud computing. So we have a mismatch of technology and context. In this case, technology was ahead of the proper context dimension in terms of customer demand and functionality and not in line with the use case — what do customers need and want?

If organizations, only focus on the product prototype at stake and subsequently disconnect it from its future context prototype, then automatically engineering efforts will put the product prototype in the present context. It is thus limited to a context that is already in place regarding its use cases. Later in the process, when the RP reaches science reality, it will actually be designed for a past environment, which results in a clash. For SFP to unleash its full potential and to be able to recognize the most valuable future opportunities, we argue that putting prototypes into their future context and use case is central. SFP forms a very well-suited method to perform this task and should be further integrated with existent creativity fostering techniques.

Developing a product application (P) for the future by considering the present context will most likely lead to an error once the application is launched. Present context is past context in the future and most likely not applicable. While idiosyncratic prior knowledge facilitates the discovery of certain opportunities by some people as opposed to others with less idiosyncratic knowledge, it is hard to discover the radically new in this setting [19]. Considering that innovators strive for something new following their wish for success, it is important that they think ahead outside the boundaries of what they already know. This means, to detect high-value future opportunities, one has to make the leap into a real prototype (RP) meeting its future context to be ahead of the curve. This cognitive approach helps entrepreneurs to discover the knowledge they need to obtain to realize new opportunities. Consequently, we propose the framework outlined in Fig. 6 as a new way of thinking about leveraging SFP to its full potential. In order to discover opportunities, entrepreneurs and innovators need to think outside their cognitive boundaries. In the subsequent section we will

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9 e.g. the 1951 novel Foundation by Isaac Asimov.
derive resulting implications for the context dimension with respect to SFP as a method.

4.6. A typology of SFP

Throughout this paper and our story vignette, we have highlighted the role of context (e.g., political, economic, social, technological, environmental, legal) in SFP. More explicitly, what are surrounding technologies, standards and how does a future society interact? In the following, we propose a classification scheme based on the extent of future context specifications and the extent of future technology specifications (Fig. 7), which is an expansion of our understanding of SFP in the future possibility space as outlined in Fig. 2. Inherent in Fig. 7 is also a time component. In Fig. 7, we suggest a classification of SFP according to their impact.

4.6.1. Radical SFP

The optimal elaboration of both dimensions requires the highest amount of effort in SFP but rewards with radical product innovations encompassed with sophisticated understanding of the interlinked environment. In our story vignette and the 2033 use case, we present a radical SFP. Another example might be found in the 3D printing scenarios by Birtchnell and Urry [10]. Radical SFP not only offers the highest potential to broaden current scientific thinking but also serves as source for inspiration in terms of how to adjust a company to potential future settings. A combination of highly science-based foresight blended with important social and cultural practices such as religion can also be seen in “Love and God and Robots” by Johnson [40].

4.7. Incremental SFP

An incremental SFP focuses most of the envisioning on product-related technology speculation. As a result, these incremental SFPs produce science fiction with constantly evolving technology or product features but due to the lack of intensive context elaboration, the innovation character will be more incremental regarding its transformative power into tangible prototypes or real products. Typically, these efforts are of highest quality but they neglect the broader context as technology seems at that point the most important. According to our understanding, the two startups in Wu [9] apply incremental SFP in science fiction transformation.

4.8. Short-term SFP

A short-term SFP is not necessarily a speculative vision of a technology development for the next 20 years (a time-frame frequently mentioned in SFP, e.g., [18]) but focuses on more near-term scenarios that are already quite in line with current trends in their early development phase. To name an example, one might consider the working paper “Internet of Mysterious Things” by McCullagh [41]. It is capturing technologies that are already working or in development as a starting point and also encompasses some degree of environmental dimension, which is not in focus.

4.9. Sustainable SFP

SFPs that are about anticipating future environment to adjust current products are most suitable for companies that do not want to change their product radically but intend to be alert to which future context this product might be facing. For instance, one might consider Coca Cola and how people will interact with the product in a futuristic story vignette and what might be e.g. upcoming health-related issues. So, Coca Cola is more interested in anticipating the future environment to adjust and improve the current product. It is an attempt to scout for future environments that might influence its future success. Hence, this can be considered as a sustainable SFP intending to ensure sustainability in future settings. The SFP “Nickelbricking” written by Moores and Atherton [42] is about a murder investigation in a future San Francisco. This is a great example of a story vignette that tries mainly to explore the future environment and its implications for a contemporary “service” which will sustain in the future, namely crime investigation.

We suggest the framework in Fig. 7 as a classification scheme for SFP. Context is important in order to promote opportunity recognition and to envisage game changing technologies and their societal impact as evident from our SFP typology.

5. Conclusion

SFP promotes creative thinking by enabling people from totally different backgrounds to share their visions of the future for technology, business and society and the interaction thereof. Drucker [43, p.16] once famously said “The best way to predict the future is to create it.” Though in a different context, we can infer from the above line of thought that what is decisive about the future is how we shape it in the present and this connects to actively shaping technology futures through sophisticated imagination [44]. According to our SFP, we are currently part of one of the largest technology revolutions in history that will re-shape production, the labor market and how our society works and interacts [21]. Fabcreation has a multitude of implications for CE and society at large. The diversity of CE
increases drastically and what is more, products can be tailored to individual needs at relatively little investment of time and financial resources. Even small quantities can be produced and ideas can be experimented with. Social production and being able to customize products will provide a more distinct personal connection to the CE product.

The paper discusses SFP as a tool for technology development through the creative elaboration on two distinct but yet strongly interconnected dimensions: The SF technology prototype and the SF context prototype (Fig. 5). We can observe from our Fabcreation example that even though parts of the technology (3D printing, printed electronics) has long been assigned a high impact, its fiction transformation only proceeds gradually rather than rapidly. A possible reason might be that the context for the technology to flourish has not been established, yet. We propose that SFP directly addresses this challenge. Focus is set on pure creativity leveraged to shape the future. Usually, our thinking is framed by the past, as we are constantly reflecting. In SFP, problems can be anticipated even before a real prototype exists. We argue that most value can be derived from SFP, if the prototypes are of the radical kind and both incorporate the product as well as the context dimension.

Our theoretical contribution underlines that entrepreneurial opportunities are not solely discovered because people rest on what they know from their experience but are highly dependent on the context in which they are regarded. This applies especially to those opportunities that have a game changing character or, in Schumpeterian terms, are highly disequilibrating [27]. This notion is supported by findings that cognitive limits and knowledge specialization prevent entrepreneurs from identifying the complete set of opportunities enabled by a given technology [32, 45]. Hence, we propose that entrepreneurial opportunities need to be regarded in their future context in order to be discovered given their enabling technology.

In terms of our practical contribution, we have followed the underlying assumption that innovative products are success factors for outcomes like financial return, competitive advantage or corporate survival (e.g. [46–48]). Thus, we anticipate that organizations constantly amend their model of corporate innovation and product development to cope with increasing customer requirements, faster changing environments, and shorter product life cycles. Given this high level of dynamism and change, methods of anticipating the future need to deal with an increasing degree of uncertainty and envisage, what is not yet foreseeable based on science fact. Science fiction prototyping constitutes such a method. Most explicitly, we should think about SFP in a more strategic fashion and our frameworks in Figs. 6 and 7 provide a solid and structured basis to do so.

Overall, it is important to note that SFP is not only a tool for large corporations. Also small firms and start-ups that can equally apply it to make a case for the necessity of their product in a future context. Technology entrepreneurs in the biotechnology or material science area use fictional outlooks, which are based on their current science fact to illustrate the potential of their innovation to investors and first customers. It is an adequate tool, as new ventures are typically in the earliest development process, often represented by a patented technology innovation paired with commercialization ideas. In our paper, we open up the field for future investigation and integration of SFP in entrepreneurship and consider an integration into entrepreneurship education as sensible. To our understanding, radical SFP is the sweet spot of the method.

5.1. Future research implications

We provide a context prototype and technology prototype perspective, which we want to put up to debate in future research on SFP. What is more, we have made a first attempt to classify SFP into a typology, which calls for future work critically assessing this approach and consolidating existent literature according to the criteria suggested. Our typology of SFP calls for a more integrative approach towards the method in emerging research. According to our literature research, the method is more and more evolving and calls for more consensus. Our typology of SFP allows for a classification of literature which has been developed so far. Clustering the literature will help to further advance the method significantly.

5.2. Limitations

We cannot simply predict the future. It is as simple as that. Thus, SFP beyond what we classify as short-term SFP, is highly speculative as soon as we introduce a context perspective in the more distant future. Accordingly, we have to be careful about these predictions and regard them as inspiration. Nevertheless, SFP is highly beneficial in visioning and being constantly engaged in thinking about the future. A core limitation to our study is that our suggested frameworks are indicative and not yet empirically validated.

Appendix A

Appendix A.1. Sample characteristics

![Graph showing sample characteristics by organizational type](image)

Fig. A1. Sample characteristics: experts by organizational type note: n = 68; source: FP7 project “Diginova - Innovation for Digital Fabrication”.

Appendix B. Biographical endnotes

Appendix B.1. Michael Potstada

Michael Potstada is a PhD candidate in management at the University of Mannheim and associated with the Graduate School of Economics and Social Sciences (GESS). In 2012, he was a visiting scholar at Scancor at Stanford University. What is more, he is a project manager at InnovationLab GmbH, an innovation company founded by industry representatives, such as BASF, Roche, Merck, SAP, and academic institutions like the University of Heidelberg and the University of Mannheim. He is participating in a FP7 consortium and
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Appendix B.2. Jan Zybura

Jan Zybura is a researcher in the fields of entrepreneurship, family business and corporate entrepreneurship at the Mannheim Institute of SME Research (ifm). He is a lecturer for Entrepreneurship (Chair of Small and Medium Sized Companies and Entrepreneurship) and Management PhD fellow at the Graduate School of Economics and Social Sciences (GESS) at the University of Mannheim, Germany.

References


Michael Potstada is a PhD candidate in management at the University of Mannheim and associated with the Graduate School of Economics and Social Sciences (GESS). In 2012, he was a visiting scholar at Scannor at Stanford University. What is more, he is a project manager at InnovationLab GmbH, an innovation company founded by industry representatives, such as BASF, Roche, Merck, SAP and academic institutions like the University of Heidelberg and the University of Mannheim. He is participating in a FP7 consortium and currently works on technology roadmapping for the European Commission.

Jan Zybura is a researcher in the fields of entrepreneurship, family business and corporate entrepreneurship at the Mannheim Institute of SME Research (ifm). He is a lecturer for Entrepreneurship (Chair of Small and Medium Sized Companies and Entrepreneurship) and Management PhD fellow at the Graduate School of Economics and Social Sciences (GESS) at the University of Mannheim, Germany.