Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 84 (2019) 790–797

www.elsevier.com/locate/procedia

29th CIRP Design 2019 (CIRP Design 2019)

InnoBandit 2.0: A Systematic Approach to Scenario-Based Product Profile Generation in PGE – Product Generation Engineering

Florian Marthaler[a*], Jonas Heimicke[a], Jia Ou[a], Nicolas Reiss[a], Nikola Bursac[b], Albert Albers[a]

[a]*Karlsruhe Institute of Technology (KIT), Kaiserstrasse 10, 76131 Karlsruhe, Germany*
[b] *TRUMPF Werkzeugmaschinen GmbH + Co. KG, Johann-Maus-Strasse 2, 71254 Ditzingen, Germany*

* Corresponding author. Tel.: +49 721 608 46051; fax: +49 721 608 46051. *E-mail address:* florian.marthaler@kit.edu

Abstract

More than ever before, innovations are transforming industries and people's lives in ways that were previously unimaginable. Due to rapid technological changes and shifting market dynamics, the economic success and organizational survival of businesses are increasingly dependent upon forward-looking strategies and innovations. The effect is the increasing popularity and adoption of scenario management across the business sector. However, the scope of future uncertainties considered in the traditional product development process is often limited, and there is yet to be a systematic approach that aids the engineers in making future-oriented development decisions in an agile fashion. Therefore, a targeted creativity method that integrates foresight and technical analysis is proposed in the present article to enable scenario-based product profile generation in the product innovation process. Adapted from the existing creativity method InnoBandit, developed at IPEK-Institute of Product Engineering, the method is derived by experts who have also been involved in the development of the first version of InnoBandit. Validation of the method is achieved through student participation in the Live-Lab AIL - Agile Innovation Lab and an expert workshop in collaboration with the industry partner Trumpf.

Keywords: innovation; creativity methods; foresight; scenario analysis; PGE – Product Generation Engineering; ASD – Agile Systems Design

1. Introduction and Motivation

In today's highly dynamic and globalized corporate environment, firms increasingly face the need to explore potential opportunities in the future while exploiting their current competitive advantages and their organizational success largely depends on continuous innovation [1]. Driven by rapid technological advances and emerging economies, innovation finds itself at the core of successful business strategy [2]. However, creating innovations is usually a graduate and iterative process, resulted from marrying various elements of a problem with those of a solution, which typically involves a thorough understanding of the situation and context as well as some external stimuli that spark inspiration [3]. Context-specific and target-oriented creativity methods can be used to stimulate innovative solutions focused on the current development task [4]. The InnoBandit aims to elicit ideas for various problems from participating developers by promoting intuitive thought associations among context-specific visual stimuli. The images fall into three categories – megatrend, microtrend, and reference product – but forecasts of future trends and product requirements are not accounted for by the current version of InnoBandit. Furthermore, the lack of a mature, validated method for creating product profiles (demand situations on markets) based on future scenarios calls for changes in the existing method [5]. This contribution presents the next generation of the tool, namely InnoBandit 2.0, which incorporates trends and forecasts to characterize the range of future uncertainties and prompt forward-looking decision-making in the product development process.

2. State of the Art

2.1. The Model of PGE – Product Generation Engineering

According to the model of PGE - Product Generation Engineering all products are developed in generations, not from

10.1016/j.procir.2019.04.313

scratch. In other words, the development of each new generation of products is based on a reference system, which contains reference elements such as precursor products internal to the company or existing products offered by the competitors within the same market or very different areas. [6]

The development process of a complex product starts with a categorized into subsystems, which are either to be modified by means of principle or embodiment variation or carried over to the new product generation to reduce cost and minimize risk [7]. The nature of the variation types is problem-driven – properly functioning subsystems are to be maintained, or carried over, to avoid the risks of unproven technologies and unnecessary investments [8]. Newly developed subsystems undergo principle variations if fundamentally different solution principles are required, or embodiment variations if only changes of shape are desired [7]. Depending on the company, market demand, technical requirements, and other specific circumstances, appropriate types of variation are determined for the subsystems of the new product generation. The continuous analysis of the knowledge of the current state of the reference system by the development team enables an increased robustness in process planning as well as a targeted identification of further required reference system elements. [6,7]

2.2. Creativity and the Innovation Process

The shift to knowledge economies in the 21st century dictates that innovation is "a creator and sustainer of performance and change" and an imperative for organizational survival [9]. By SCHUMPETER's theory, innovation is "the setting up of a new production function" which "combines factors in a new way" [10]. ALBERS ET AL. broaden this definition and see innovation as translating the right product profile into the appropriate technical invention, which is then successfully launched on the market [11]. At the heart of the innovation process lies creativity, which, seen from a social-psychological perspective, can be attributed to three main factors: expertise, creativity skills, and task motivation [12]. This componential framework for conceptualizing creativity gives insight into how the interactions of "cognitive abilities, personality characteristics, and social factors" lead to creative ideas, thus suggesting that external factors can be manipulated to enhance one's creative capacity under favorable conditions [12]. Furthermore, creativity training programs have achieved varying levels of success across different industries with evidence showing performance enhancement [13]. By applying solution-finding methods, it is possible to systematically support engineers in the creative process and tap into their creative potential [14]. Many creativity tools and techniques are deployed in such training schemes, but little empirical research exists on which tools are effective in which particular settings [15]. The problem becomes especially complex in product engineering because innovation processes differ depending on the firm's competitive strategy and the stage of development exhibited by the production process technology [16]. Furthermore, a common barrier to translating creative ideas into technical solutions is the lack of context and targeted stimulation in the creative methods [4]. Free creativity is inefficient in agile development processes, which are often characterized by tight time constraints and rapid completion of tasks, because it can lead to increased iteration cycles and extended development times [4]. Therefore, to harness the development team's full creative potential, certain requirements and boundary conditions need to be imposed in the innovation process to achieve desired goals in agile processes while maintaining the quantity and quality of the creative ideas generated.

2.3. Demand-Driven Product Innovation Using ASD – Agile System Design

Innovation is a complex, multilevel, and time-consuming process that requires skillful leadership and management [17]. It is subject to shifting market dynamics and is "at once the creator and destroyer of industries and corporations" [18]. Therefore, as much as innovation is valued in the current business climate, companies can run into major pitfalls if it is not carefully managed – the potential risks associated with new product development can be as great as, if not greater than, the opportunities brought by innovative breakthroughs or new market penetration. The high failure rate of new products is often attributed to a false understanding of customer needs rather than technical shortcomings [19]. To handle the uncertainties associated with new product development and tackle complex projects in volatile markets, companies are increasingly adopting agile methods in the product development process [20]. The ASD – Agile System Design provides a holistic and structured approach for the agile development of mechatronic systems, allowing companies to be flexible and responsive to changing product requirements as well as uncertain market conditions [4]. ASD allows the adaptation of development procedures (sequential or iterative) at different process levels (macro to micro) according to the respective development situation. This ensures that the development team always achieves the level of agility necessary to accomplish a particular task. The decisive factor here is planning stability, which is associated with various problems (see Fig. 1). By this ASD allows iterative design cycles in which incremental changes are made to the product's functionality, and value is delivered throughout the development process. By incorporating client feedback early and frequently at each milestone, product requirements can be more easily gauged to ensure that adaptations of the product are made in a timely manner. [21]

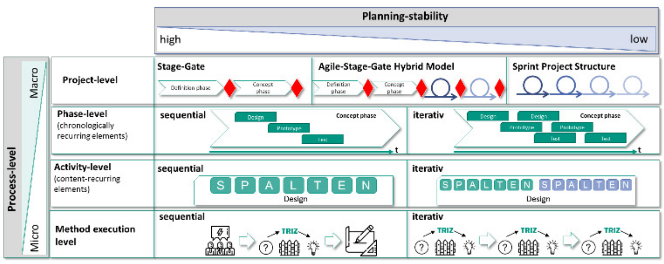

Fig. 1. ASD – Agile System Design [21].

2.4. InnoBandit – Targeted Creativity Method in Agile PGE Processes

In response to the lack of targeted simulation in existing creativity methods, an intuitive, flexible, and goal-oriented method named InnoBandit was created as a methodical approach to creative problem-solving. InnoBandit was developed based on the *Random Picture Technique*, which aims to evoke creative solutions to a pre-defined challenge by presenting an arbitrary image unrelated to the task at hand [22]. Although effective at eliciting unconventional ideas, the lack of correlation between the selected image and the challenge in the *Random Picture Technique* leads to excess creativity and therefore is unsuitable for agile PGE processes [4]. InnoBandit, shown in Fig. 2, extends the technique to three parallel appearing images, each of which falls into a certain category. Similar to how a slot machine operates, the three images are changed simultaneously every time the start button is pressed.

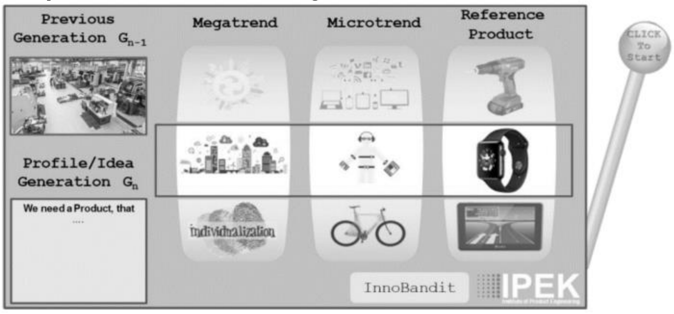

Fig. 2. Graphical representation of the InnoBandit [4]

The three main components of InnoBandit – *task definition, impulse images, and result space* – are intended to guide the participant's creative thinking in the problem-solving process. The task definition is represented by an image of the previous product generation G_{n-1}, prompting an intuitive examination of the product in development, which corresponds to the first step in the agile PGE process [6]. The impulse images are organized into three categories: *Megatrend, Microtrend, and Reference Product*, and one image from each category is presented to the viewer during each round. The *Megatrend* describes the sustained global forces of development with respect to social, economic, and technological changes that have long-term impact on the future world [23]. The *Microtrend* illustrates novel technologies or innovations across various industries that could be referenced in the current development task. The *Reference Product* depicts existing products in the specific sector and sheds light on similar technologies and design concepts. The three impulse images combined aim to provide context to the current development task and trigger thought associations among the visual stimuli in a way that channels creativity into innovative product ideas. Validation of the creativity method is achieved through workshops in which selected groups of students are tasked with developing new product concepts in collaboration with an industry partner. Here, various creativity methods such as brainstorming and the persona method are used; upon analysis of the results, InnoBandit is shown to be effective in eliciting product ideas superior in both quantity and quality. [4]

2.5. Product Profiles: Modelling Stakeholder Benefits

Synthesizing various theories on inventions and innovations, it is possible to conclude that innovations have great economic relevance and are closely linked with market dynamics [24]. As opposed to inventions, which are more concerned with the novelty of the created products or services, innovations place a larger emphasis on fulfilling market demands and adding value for the customers [10]. Therefore, successful innovations are not created in isolation but rather in tandem with careful considerations of the unmet needs of the customers in the market. According to the ASD approach, it is paramount to identify potentials in the early stages of product engineering by means of systematic identification of product profiles. A product profile, is part of an initial attempt to identify an appropriate market segment and model the product's intended benefits for all the key stakeholders. Such benefits are considered from the perspective of the customer, the provider, and the user, along with other determining factors such as reference products, use cases, and market demand. Rather than a blueprint for technical realization, the product profile provides a holistic view of the product to be developed without anticipating the technical solution and is the basis for validation for future ideas, concepts, and prototypes. [11]

2.6. Application of Scenario Analysis in Product Generation Engineering

Traditionally, future-oriented decision-making heavily relies on the predictions of experts to achieve effective management; however, strategic analysis based on the extrapolation of past and current trends and personal expectations often neglects discontinuous change and underestimates the range of varying conditions [25]. Moreover, traditional methods such as the use of subjective probabilities are often affected by cognitive biases such as overconfidence, and therefore are unlikely to lead to reliable forecasts of the future [26]. Instead of showing a single facet of a forecasted future, scenario analysis aims to capture the full range of perceived possibilities and is a powerful tool for managing risks associated with unexpected outcomes [27]. The scenario technique, consisted of five phases – scenario preparation, field analysis, scenario forecasting, and scenario transfer – allows early identification of changes and uncertainties in future product requirements such that companies can take anticipatory measures to minimize development risks [28]. By constructing detailed narratives of a host of possible futures, the scenario method systematically explores correlations between various influencing factors under certain conditions and accounts for elements that cannot be formally modelled by mathematical simulations, such as government regulations and value shifts [29]. In the case of radical innovations, prospective scenarios can be used to simulate new experiences and unmet needs unrealized by potential customers in order to identify latent opportunities in the market [30]. The use of foresight is particular valuable in PGE because the ramifications of present-day development decisions often extend into the far future, and development risks are positively correlated with the strategic time horizon as the range of uncertainties increases [5]. This is to say that intrinsic to the development process is the time-dependency of the product requirements – development activities required ten years from now can be fundamentally different from those in the present time due to market uncertainty and technological changes. Hence, a systematic, future-oriented approach is needed to help engineers make informed decisions about future product requirements while minimizing development risks. To this end, a previously developed product platform architecture is employed to elucidate the function-structure relationships underlying the product in development. Defined by Ulrich, a product architecture is the "scheme by which the function of a product is allocated to physical components" [31]. A robust product platform architecture reduces engineering effort and time-to-market for future product generations and allows companies to be more adaptable to future external drivers of change, such as changes in customer requirements [32]. Based on the product architecture, subsystems of the current product generation are evaluated with regard to their functions, which are related to the customer requirements and other qualitative demands. These product demands are translated into product properties that can be experienced by customers and then are analysed in the context of consistent future scenarios. Relevant product properties are derived and prioritized based on a set of metrics, including agreement with predicted trends, estimated degree of variation, and consistency among scenarios. Subsequently, subsystems in development can be distinguished by methodically integrating scenario analysis and PGE based on the initial product architecture shown in Fig. 3. In essence, scenario-based PGE allows systematic consideration of future possibilities in the development process and aids the strategic prioritization of development tasks based on the PGE variation types as well as the time of variation of individual product properties.

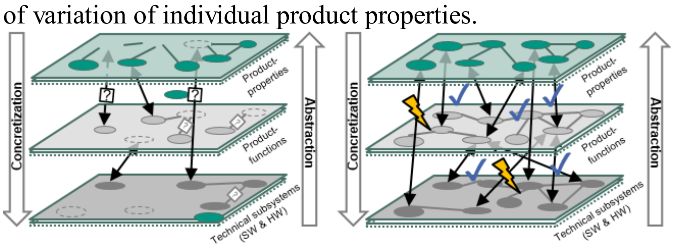

Fig. 3. Initial system of objectives in terms of product properties, product functions, and technical subsystems [33]

3. Research Methodology

The present state of research is investigated primarily through literature review and expert interviews. To integrate the element of foresight into the current version of InnoBandit and enable scenario-based product profile generation in early stages of PGE, the proposed creativity method is developed by answering the following research questions:

- What are the requirements for integrating foresight into creativity methods?
- Which components of InnoBandit need to be adapted to incorporate scenario analysis into the innovation process in agile PGE?
- Does the inclusion of a possible scenario achieve desired effects of nudging the engineers towards future-oriented design thinking?

The requirements for InnoBandit 2.0 are identified based on interviews with experts in design methodology and management. Guided by the lastest research results in scenario-based PGE, experts who were involved in creating the current version of the method are asked to give recommendations on the requirement profile of InnoBandit 2.0. To determine which components should be modified to integrate scenario analysis into the existing creativity method, a prototype is built and tested in a Live-Lab AIL – Agile Innovation Lab – workshop. In AIL a student development team develops innovative solutions to a task from an industrial company, following the six phases of the ASD – meta process. [34, 35]

After incorporating feedback from the workshop, the components of InnoBandit 2.0 are finalized, and the revised method is validated in two creativity workshops – one with students and the other with industry professionals at the company Trumpf who are knowledgeable about the product in development. The steps of the research process are outlined in Fig. 4.

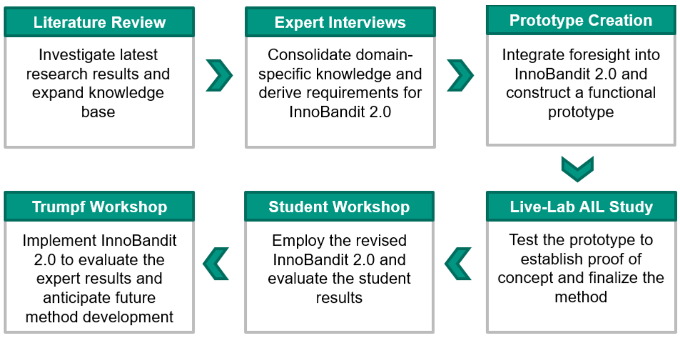

Figure 4 Methodical approach to enabling scenario-based product profile generation.

Validation in the student workshop explores the method's potential as a generic tool to help people with limited background knowledge about the product in development engage in the innovation process. Further validation in the Trumpf workshop verifies the practicality as well as transferability of the method in industrial contexts.

4. Results

4.1. Requirement Profile of a Future-Oriented Creativity Method

In order to develop a creativity method suitable for scenario-based product profile generation, InnoBandit was chosen as a reference method due to its demonstrated effectiveness in stimulating creative product ideas in agile development processes.

The impulse images in the three categories – *Megatrend*, *Microtrend*, and *Reference Product* – can be easily adapted to align with the development task without major preparation. However, there lacks a structured approach to formulating a concise, targeted task definition in InnoBandit. Experienced project leaders who had used the method in the past indicated it was often difficult for the development team to pinpoint the problem to be solved, suggesting a need for a systematic way to develop a well-defined task definition. The implications of the scenarios are the recommended times of variation for the customer-experienceable product properties. Depending on the target time of delivery and strategic priorities of the firm, relevant product properties are determined, and one is selected to be the focal point of a particular creativity workshop. As a result, the relevant subsystems can be isolated by mapping the chosen product property to the physical components based on the product architecture. Therefore, scenario analysis offers a structured approach that provides clarity to the task definition, which focuses on a chosen product property and its related subsystems in development. The emphasis on the customer-experienceable product property reflects the essence of customer-centric innovation, which underscores a thorough understanding of the customers' needs in the innovation process in order to deliver results that fulfil market expectations (Selden & MacMillan, 2006). Additionally, InnoBandit is a multifaceted creativity method in that each category targets an important factor to be considered in product design and introduces a different perspective in the innovation process. The question remains, however, as to how to seamlessly integrate the results of scenario analysis into the existing creativity method in order to inform the participant of future product requirements. Scenarios in the form of narratives, storyboards, and videos were available for use in the prototype. Based on interviews with experts in design methodology and management as well as students who had previous exposure to this subject, it was determined that a scenario video should be included in the method because it is the most entertaining and therefore is more likely to elicit emotional responses and arouse creativity. Moreover, it was also determined that characteristics of the chosen scenario should be represented in image format alongside the other impulse images to remind the participant of the influencing factors that could impact future product design.

4.2. InnoBandit 2.0 – Scenario-based Product Profile Generation

The requirement profile for a future-oriented creativity method served as the blueprint for InnoBandit 2.0, and a prototype was built based on feedback from the expert interviews. The new method incorporates a scenario in video format as well as a succinct textual explanation of the development task. The scenario video is intended to provide context for the development task and nudge the developers toward future-oriented thinking. Immediately following the video, a short task description is presented detailing the requirements of the new product generation as well as other relevant information. The task description ensures that the expectations of the company are clearly communicated before the ensuing creativity session.

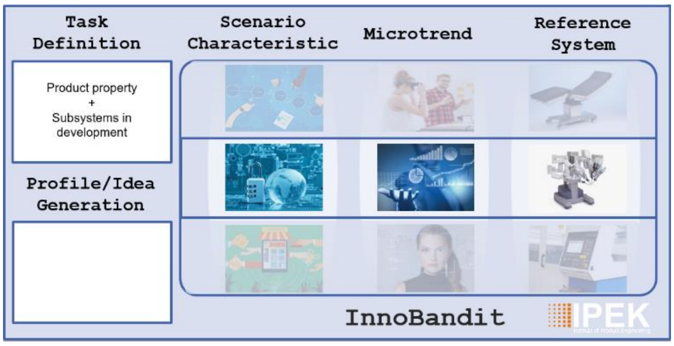

Fig. 5. Graphical representation of InnoBandit 2.0

Many main features of the current creativity method are retained in InnoBandit 2.0. The visual field is divided into *task definition, impulse images*, and *result space* as before, but necessary changes are made to improve the method's consistency with scenario-based PGE as illustrated in Fig. 5.

A major distinction resides in the *task definition*, which in InnoBandit 2.0 revolves around a chosen customer-experienceable product property as well as its related subsystems rather than an arbitrarily determined topic to ensure that the generated product profiles do not deviate from the development task. The categories of the *impulse images* are also modified to facilitate thought associations that relate characteristics of a probable future, influential forces of development in the sector, and existing innovative technologies to the development planning process. The visual stimuli are assigned to three categories: *Scenario Characteristic*, *Microtrend*, and *Reference System*. The *Scenario Characteristics* represent external drivers of change identified in scenario development that can be translated into qualitative future product requirements. These images are intended to remind the developers of hypothetical use cases of the product in the future, thus aiding current product design decisions in support of future product-market fit. The *Microtrends* are adapted from the precursor method and are chosen over the megatrends based on feedback from the AIL workshop. Instead of characterizing long-lasting trends that are all-encompassing in today's society and often too frequently mentioned to evoke creativity, microtrends show concrete examples of how shifts in technology, social trends, and values have resulted in ground-breaking innovations in the market and are reported to be more stimulating than megatrends. The counterpart of reference products in the precursor method, the *Reference Systems* in InnoBandit 2.0 focus on the specific subsystems in development and depict existing technologies implemented in similar products. By pinpointing the individual subsystems, this category highlights the features and specifications of the subsystems in development, thus bringing the resulting product ideas to a narrower focus.

4.3. Evaluation in Student and Industry Expert Workshops

Evaluation and validation of InnoBandit was done in a series of three workshops involving students and industry professionals as summarized in Table 1.

Table 1. Summary of the experimental design.

	Test Group 1	Test Group 2	Test Group 3
Partici-pants	Students	Students	Industry ex-perts
Group size	6	3	3
Creativity method(s)	InnoBandit 1.0 (n=3) InnoBandit 2.0 (n=3)	InnoBandit 2.0	InnoBandit 2.0
Evalua-tion crite-ria	Survey	Quantity Innovation po-tential Time-to-market	Quantity Innovation po-tential Time-to-market

Initial proof of concept of the method was achieved in an AIL – workshop, which consisted of six student participants evenly divided into two groups. A Live-Lab is a research environment designed to foster the development of transferable knowledge in industrial contexts using scientific methods, combining the advantages of industry field research with those of laboratory studies. The students were familiar with principles of product design and agile development methodologies because of involvement in previous industry development projects. Both versions of InnoBandit were employed independently in the workshop, and a survey was administered at the end to collect feedback on the method application. In the survey, statements about the creativity method used in each group were rated on a Likert scale from "strongly agree", which has a score of 5, to "strongly disagree", which has a score of 1. The survey responses indicated that InnoBandit 2.0 scored higher than InnoBandit 1.0 in terms of future-oriented thinking, usefulness for the development task, and likelihood of future use. The average scores for these three areas are tabulated in **Table 2**. Based on verbal feedback and survey responses from the AIL workshop, necessary changes were made to improve the clarity and ease-of-use of the method, and the components of InnoBandit 2.0 were finalized.

Table 2. Average scores for InnoBandit 1.0 and 2.0 from the AIL survey.

Category	InnoBandit 1.0 (n=3)	InnoBandit 2.0 (n=3)
Future-oriented thinking	3.3	4.3
Usefulness for the development task	3.7	4.0
Likelihood of future use	3.7	4.0

After establishing proof of concept, InnoBandit 2.0 was applied in two other creativity workshops to investigate its effectiveness in catalyzing future-oriented product profile generation. The predefined development task focused on innovative laser cutting technologies and was assigned in both workshops. The first workshop was conducted with students who had no prior experience working with the product in development, and the second one involved professionals from the company Trumpf who were experts in the field. The resulting product profiles from both workshops were assessed by the Trumpf experts. In particular, the *quantity*, *innovation potential*, and *time-to-market* of the product ideas were evaluated.

Table 3. Quantity of generated product profiles using InnoBandit 2.0 in the student and Trumpf workshops.

	Non-Experts (n=3)	Experts (n=3)
Total number of product profiles	15	11
Focused on product property	9	8
Focused on target sub-systems	11	7
Focused on product property and target sub-systems	9	6

For the *quantity* criterion, the number of generated product profiles was documented with respect to each workshop. In addition, the profiles were classified according to their fit with the product property as well as focus on the target subsystems. It can be seen from Table. 3. the results from the student and Trumpf workshops are comparable in terms of quantity, indicating that InnoBandit 2.0 increased the creative capacity of the non-experts, or people unfamiliar with the product in development, who otherwise would have to solely rely on intuition and would likely have fewer ideas without a structured creativity method. Quality of the product ideas is graphically represented in a framework consisting of *innovative potential* and *time-to-market*. The criterion *innovative potential* is indicative of the level of creativity behind the ideas and more importantly reflects their likelihood to become successful in market. *Time-to-market* measures the length of time between a product's ideation and its launch and is determined based on a host of determining factors including development costs, competitive landscape, market opportunity, and product performance (Bayus, 1997). These two measures together helped the Trumpf experts assess the value of the product profiles obtained from the two creativity workshops, and the replicated results are shown in Fig. 6. Product ideas located at the lower-left corner of each graph were deemed attainable but with low innovative potential, whereas those located at the upper-right corner were considered idealistic and too demanding to be achieved given the company's technical capabilities. The ideas receiving positive recommendations were thought to have high innovation potential and relatively short time-to-market, which can be found toward the middle of the horizontal axis. Analysis of the visual representation of the product profiles suggests that while the student results were greater in number, the expert results had higher quality because 73% of the expert results (8 out of 11), contrasted with 33% of the student results (5 out of 15), received positive feedback from the experts.

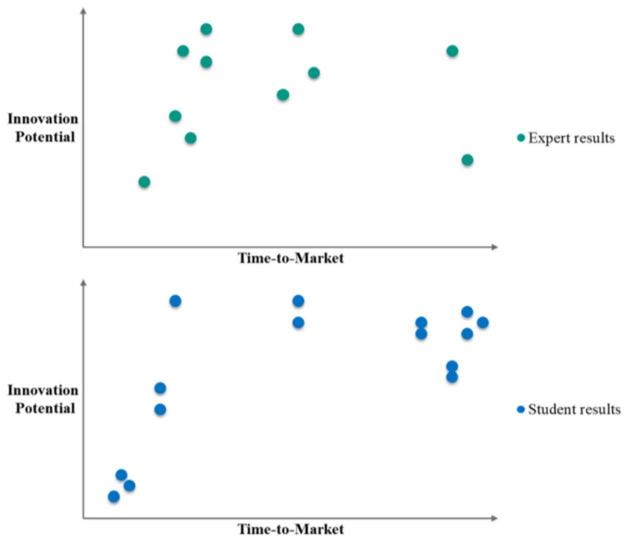

Fig. 6. Graphical representation of the innovative potential and time-to-market of the product profiles.

Quantitative and qualitative analyses of the results from the student and expert workshops confirmed the usefulness of InnoBandit 2.0 as a creativity method in the agile innovation process. The method can promote creativity thinking especially in the non-experts, helping them engage with the development task and generate many creative ideas despite lack of domain-specific knowledge. Validation in the Trumpf workshop supported the method‘s applicability in industry projects and demonstrated the method‘s effectiveness in eliciting high-quality product ideas from experienced developers.

5. Conclusion and Outlook

Building upon an existing creativity method, InnoBandit 2.0 was developed in accordance with agile PGE methodologies to incorporate foresight into the product innovation process. Using a customer-centric approach, the method integrates scenario analysis and subsystem analysis by focusing on the product's customer-experienceable properties one at a time and each property's associated technical subsystems. The method uses images of *Scenario Characteristic*, *Microtrend*, and *Reference System* as visual stimuli to target thought associations on the subsystem level, intuitively tying in future product requirements and current innovative technologies. Instead of randomly combining impulse images during each round of idea generation as in its precursor method, InnoBandit 2.0 utilizes a predefined product architecture relating the functions and physical components of the product in development to avoid potentially distracting thought associations. Validation of the method in creativity workshops has demonstrated its effectiveness in promoting creative thinking and aiding future-oriented design decisions. It was especially useful in supporting people with no prior experience with the product in development in terms of increasing the quantity of their ideas; however, higher performance was observed among industry experts given their knowledge about the product as well as the market. Therefore, one area of future improvement is to increase the quality of the product ideas generated by the non-experts. In addition, expert feedback indicated that further work needs to be done in terms of understanding the developers' pain point and taking them on a mental journey from the identification of the relevant product properties to the development of product profiles in the context of the scenario. Hence, the results of InnoBandit 2.0 lay the foundation for further investigation into scenario-based product profile generation and point to the direction in which subsequent methods are needed.

References

[1] Duane Ireland R, Webb JW. Strategic entrepreneurship: Creating competitive advantage through streams of innovation. Business Horizons. 2007;**50**:49–59. DOI: 10.1016/j.bushor.2006.06.002

[2] Teece DJ. Business Models, Business Strategy and Innovation. Long Range Planning. 2010;**43**:172–194. DOI: 10.1016/j.lrp.2009.07.003

[3] Birkinshaw J, Hamel G, Mol MJ. Management Innovation. Academy of Management Review. 2008;**33**:825–845. DOI: 10.5465/amr.2008.34421969

[4] Heimicke J, Reiss N, Albers A, Walter B, Breitschuh J, Knoche S, Bursac N. Agile Innovative Impulses in the Product Generation Engineering: Creativity by Intentional Forgetting. Proceedings of 5th International Conference on Design Creativity (ICDC 2018). 2018:183-190

[5] Albers A, Dumitrescu R, Marthaler F, Kuehfuss D, Strauch M, Siebe A, Bursac N. PGE-Produktgenerationsentwicklung und Zukunftsvorausschau: Eine systematische Betrachtung zur Ermittlung der Zusammenhänge. 14. Symposium für Vorausschau und Technologieplanung, Berlin, 8.-9.11.2018, 23

[6] Albers A, Rapp S, Spadinger M, Richter T, Birk C, Marthaler F, Heimicke J, Kurtz V, Wessels H. The Reference System in PGE - Product Generation Engineering: A generalized Understanding of the Role of Reference Products and their Influence on the Development Process. Proceedings of 22nd International Conference on Engineering Design ICED 2019

[7] Albers A, Rapp S, Birk C, Bursac N. Die Frühe Phase der PGE – Produktgenerationsentwicklung. Stuttgart, Germany; 2017

[8] Eckert CM, Alink T, Albers A. ISSUE DRIVEN ANALYSIS OF AN EXISTING PRODUCT AT DIFFERENT LEVELS OF ABSTRACTION. DS 60: Proceedings of DESIGN 2010, the 11th International Design Conference, Dubrovnik, Croatia. 2010:673–682

[9] Serrat O. Harnessing Creativity and Innovation in the Workplace. In: Serrat O, editor. Knowledge Solutions: Tools, Methods, and Approaches to Drive Organizational Performance. Singapore, s.l.: Springer Singapore; 2017. p. 903–910. DOI: 10.1007/978-981-10-0983-9_102

[10] Schumpeter JA. Business Cycles: A Theoretical, Historical and Statistical Analysis of the Capitalist Process. New York: McGraw-Hill; 1939

[11] Albers A, Heimicke J, Walter B, Basedow GN, Reiß N, Heitger N, Ott S, Bursac N. Product Profiles: Modelling customer benefits as a foundation to bring inventions to innovations. Procedia CIRP. 2018;**70**:253–258. DOI: 10.1016/j.procir.2018.02.044

[12] Amabile TM. The social psychology of creativity: A componential conceptualization. Journal of Personality and Social Psychology. 1983;**45**:357–376. DOI: 10.1037/0022-3514.45.2.357

[13] Scott G, Leritz LE, Mumford MD. The effectiveness of creativity training: A quantitative review. Creativity Research Journal. 2004;**16**:361–388. DOI: 10.1080/10400410409534549

[14] Graner M. Der Einsatz von Methoden in Produktentwicklungsprojekten: Eine empirische Untersuchung der Rahmenbedingungen und Auswirkungen. 2013rd ed. Wiesbaden: Springer Gabler; 2012

[15] Vernon D, Hocking I, Tyler TC. An Evidence-Based Review of Creative Problem Solving Tools. Human Resource Development Review. 2016;**15**:230–259. DOI: 10.1177/1534484316641512

[16] Utterback JM, Abernathy WJ. A dynamic model of process and product innovation. Omega. 1975;**3**:639–656. DOI: 10.1016/0305-0483(75)90068-7

[17] Anderson N, Potočnik K, Zhou J. Innovation and Creativity in Organizations. Journal of Management. 2014;**40**:1297–1333. DOI: 10.1177/0149206314527128

[18] Utterback JM. Mastering the dynamics of innovation: How companies can seize opportunities in the face of technological change. 2nd ed. Boston: Harvard Business School Press; 1994

[19] Ogawa S, Piller T. Reducing the Risks of New Product Development. MITSloan Management Review. 2006;**47**:65–71

[20] Schmidt TS, Paetzold K, Weiss S. Agile Entwicklung physischer Produkte. VDI-Statusreport 09/2018

[21] Albers A, Heimicke J, Spadinger M, Reiss N, Breitschuh J, Richter T, Bursac N, Marthaler F. Eine Systematik zur situationsadäquaten Mechatroniksystementwicklung durch ASD – Agile Systems Design. in KIT Scientific Working Papers. 2019; 113, KIT, Karlsruhe. https://doi.org/10.5445/IR/1000091847

[22] Brunner A. Kreativer denken: Konzepte und Methoden von A - Z. München: Oldenbourg; 2008

[23] Fontius J. Megatrends und ihre Implikationen für die Logistik: Ableitung von Wirkungszusammenhängen. Vol. 25. Universitätsverlag der TU Berlin; 2014

[24] Ruttan VW. Usher and Schumpeter on Invention, Innovation, and Technological Change. The Quarterly Journal of Economics. 1959;**73**:596. DOI: 10.2307/1884305

[25] Peterson GD, Cumming GS, Carpenter SR. Scenario Planning: a Tool for Conservation in an Uncertain World. Conservation Biology. 2003;**17**:358–366. DOI: 10.1046/j.1523-1739.2003.01491.x

[26] Makridakis, S., Gaba, A. Judgement: Its role and value for strategy. INSEAD, Fontainebleau, France.

[27] Fink, A., Siebe, A., Kuhle, J. P. How scenarios support strategic early warning processes. foresight. 2004;**6**:173–185

[28] Gausemeier J, Plass C, Wenzelmann C. Zukunftsorientierte Unternehmensgestaltung: Strategien, Geschäftsprozesse und IT-Systeme für die Produktion von morgen. München: Hanser; 2009

[29] Schoemaker PJH. Scenario planning: A tool for strategic thinking. Sloan Management Review

[30] Moon, H., Han, S. H. A creative idea generation methodology by future envisioning from the user experience perspective. International Journal of Industrial Ergonomics. 2006;**56**:84–96

[31] Ulrich K. The role of product architecture in the manufacturing firm. Research Policy. 1995;**24**:419–440. DOI: 10.1016/0048-7333(94)00775-3

[32] Martin MV, Ishii K. Design for variety: developing standardized and modularized product platform architectures. Research in Engineering Design. 2002;**13**:213–235. DOI: 10.1007/s00163-002-0020-2

[33] Hirschter T, Heitger N, Haug F, Fahl J, Mandel C, Marthaler F, Walter B, Albers A. Zukunftsorientierte PGE – Produktgenerationsentwicklung: Ein Ansatz zur systematischen Überführung von Szenarien in Produktprofile in der Frühen Phase der PGE. 14. Symposium für Vorausschau und Technologieplanung (SVT)

[34] Albers A, Bursac N, Heimicke J, Walter B, Reiß N. 20 years of co-creation using case based learning: An integrated approach for teaching innovation and research in Product Generation Engineering. In: Auer ME, Guralnick D, Uhomoibhi J, editors. Proceedings of the 20th ICL Conference. Springer; 2017. p. 636–647. DOI: 10.1007/978-3-319-73204-6_69

[35] Albers A, Heimicke J, Hirschter T, Reiß N, Maier A, Bursac N. Managing Systems of Objectives in the agile Development of Mechatronic Systems by ASD – Agile Systems Design. Proceedings of NordDesign 2018