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Quantifying Characteristics of Iterations in the Fuzzy Front End of Product Development Processes

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Abstract

While iterations are an inherent phenomenon in product development processes (PDPs), research in the fuzzy front end (FFE) of PDPs concerning their characteristics and effectiveness, as well as iteration patterns, is scarce. We address our research question 'which characteristics of iterations occur in the FFE of PDPs?' with an empirical and quantitative research approach by observing teams in facilitated ideation workshops. We develop a framework of quantified iteration characteristics and identify patterns of effective iteration sequences. As practical implication, the insights can support the facilitation of ideation workshops.

Keywords: SME, Ideation Workshop, Product Development Process, Prototyping, Iteration

1 Introduction

Iterations are an inherent phenomenon in product development processes (PDPs) and occur with manifold characteristics. While a lot of research is based on theoretical reasoning and simulations, Wynn et al (2007) conclude "that process simulation models cannot capture all possibilities for iteration in an [new product development] project", and also Smith & Tjandra (1998) call for more research by *direct observation* regarding iterations in industrial projects, i.e. with design teams. Moreover, simulations indicate that PDP performance can be increased by accelerating required iterations and making them happen earlier (e.g. Martinez Leon et al 2013a, 2013b), e.g. in the fuzzy front end (FFE) of PDPs. Thus, it would be interesting to shed more light on iterations in the FFE of 'real' PDPs, to characterize them *in-situ* and to quantify their occurrence and effectiveness. Moreover, there might not only be single effective iterations, but patterns of effective iteration sequences, as there is e.g. a divergence/convergence pattern in PDPs (e.g. Liu et al 2003). Thus, we address our research question '*which characteristics of iterations occur in the FFE of PDPs?*' with an empirical and quantitative research approach.
In the following, section 2 reviews literature regarding iterations in PDPs, while section 3 explains our research design. Section 4 presents a framework with the quantified characteristics of iterations in the FFE of PDPs, section 5 discusses these results, and section 6 concludes.

2 Background and related literature

While a lot of research addresses mental and cognitive iterations of individual designers (cf. Miller et al 1965; Adams & Atman 1999; Jin & Chusilp 2006), we focus on iterations in PDPs undergone by multi-disciplinary teams. More specifically, we review (1) when and at which scale iterations occur, and (2) who is dealing with these iterations.

2.1 Occurrence and scale of iterations

Smith & Tjandra (1998) highlight the *scale* of iterations, ranging from small design optimization algorithms for calculating factor loadings, to car manufacturers who determine the requirements for the next car generation based on the current market response.

When focus is put on iterations in PDPs based on the Stage Gate process, Unger & Eppinger (2011) define (1) *reviews* as "strict, checklist-style design reviews before a new stage can begin" and (2) *iterations* as "iterations within some stages are normal, but cross-phase iterations are an unusual sign of trouble", in order to establish a PDP design method based on risk, iteration and review. From a more practical view point, Meboldt et al (2012) highlight the dilemma of managing iterations in time-to-market PDPs by distinguishing between "*worst case iterations*" (i.e. issues popping up after market launch leading to product recalls and a loss of reputation), serious *cross-gate iterations* which occur due to a falsification of gate decisions, and targeted *in-stage iterations* which happen within development stages and lead to an increased product maturity. While the latter ones can occur at any point of time in the PDP, the cross-gate iterations (especially in their worst case) occur at later stages of the PDP.

In contrast to these industrial practice experiences, Martinez et al (2011) and Martinez Leon et al (2013a, 2013b) investigate how implementing front-loading principles from Concurrent Engineering (CE) literature can lead to improved product development performance with help of Design Structure Matrixes (DSMs) and simulations. Therefore, they distinguish between "*pseudo* feedback loops" and "*irreducible* loops", whereas the former can be avoided, and the latter shifted to an early stage of the PDP. Thus, their intent is to increase PDP performance by accelerating required iterations, making them happen earlier, and "minimizing counter-productive iterations" such as engineering design changes. Similarly, Kantomaa (2012) classifies harmful iterations (causing rework & repetition, and caused by external factors), diagnoses their impacts, and develops means to diminish these impacts based on a systems dynamics model. Moreover, he develops an *iterative development model* that aims at "early, feedback providing iterations for avoiding later harmful iterations". And already Smith & Eppinger (1997) developed the work transformation matrix model to predict the convergence speed of iterations in a project, as well as identifying design sub-problems which require more iterations to reach a feasible solution. They recommend two strategies: "faster iterations and/or fewer iterations" and suggest several means how to implement either strategy.

Krehmer et al (2009, 2010) distinguish between the "*progress of the development process*" and "*product's degree of maturity*" which is seen as the relevant measure of the customers' requirements. Based on the connection between the product's maturity and PDP iterations, they introduce a measure for the evaluation of iterations and their effects onto the product's maturity. Thus, it supports to carry out only those iterations which are manageable and have useful impact.

To summarize, iterations can occur in a broad range of scale, and at every point in time during PDPs. Some authors argue that early (and quick) iterations might have a positive effect on the outcome of PDPs. Thus, we investigate these early iterations and their effectiveness in more detail.

2.2 Management and engineering design perspective

Heck et al (2015a) describe a management- and engineering design perspective on iterations. While the former perspective perceives a "negatively connoted impact onto the business", the latter considers iterations as an "inherent and necessary phenomenon in PDPs to improve a forthcoming product's quality." In the following, we investigate both perspectives in detail.

2.2.1 Management perspective

From a management perspective, iterations can be linked with uncertainty and performance. Regarding uncertainty, Smith & Eppinger (1993) distinguish between *expected iterations* and *unexpected iterations*. Especially regarding the unexpected iterations, Levardy & Browning (2005) highlight the flawed assumption of several conventional project planning techniques that activities and their relation are known *a priori*, and develop the "adaptive test process" approach to dynamically recombine activities based on the evolving project's state and progress. While these decisions are taken under uncertainty, the approach considers risk (uncertainties and their impact). Yang et al (2014a) investigate the impact of uncertainty and ambiguity by discrete-event simulation modeling, characterizing uncertainty with the variables: *iteration probability*, *iteration length*, *number of iterations*, and *activity's learning curve effect*. They derive the imperative to control iteration and activity overlapping in order to reduce uncertainty and ambiguity. Especially overlapping tasks may lead to conflicts – both content- and scheduling wise. Thus, Yang et al (2014b) model the overall task load in PDPs and analyze features of task iteration convergence, leading to a "design capability reliability evaluation model" which allows to evaluate conflicts between design capabilities and task iteration. They suggest measures for reducing task iteration frequency and optimizing conflict processes.

Regarding performance, Drury-Grogan (2014) uses case studies to investigate the performance of agile teams and finds that teams discuss the four categories of iteration objectives: *Functionality*, *Schedule*, *Quality*, and *Team Satisfaction*. Furthermore, teams' critical decisions are examined and categorized into: Quality, Dividing Work, Iteration Amendments, and Team Satisfaction. About a decade earlier, Ford & Sterman (2003) showed the critical role of iterations in explaining the "*90% syndrome*", an often occurring form of schedule failure during CE. They state, that iterations can delay projects by (1) occurring more often, (2) the distance that information must travel, (3) the speed of traversing this distance, and (4) occurring later than necessary. With their systems dynamics model they identify "the need for explicitly including iteration" and suggest for further research to identify test metrics relating iteration to project performance and "how specific iteration features constrain progress."

To summarize, the management perspective is concerned with uncertainty reduction and risk mitigation, as well as in charge of performance improvements. Moreover, the authors merely applied modeling/simulation approaches in their research. Thus, it would be interesting whether performance measures can also applied to 'real' PDPs to derive levers for PDP improvements.

2.2.2 Engineering design perspective

From an engineering design perspective, there are two different approaches to describe iterations. On the one hand, there are definitions of *what elements* iterations consist, and on the other hand, with *which characteristics* they appear.

Regarding the elements, Smith & Tjandra (1998) define iterations as "*cycles of proposal, testing, and modification of an evolving design*" (i.e. an analysis-synthesis cycle) and utilize a lab experimental setting to observe iterations. They videotaped nine groups of four students who solved an artificial design problem in sessions of about 2-3 hours. They observed several patterns of behavior such as (1) little discussion during the process, (2) an early non-iterative period of the process consisting of information sharing and structure development, (3) analysis phases become longer during the process progress (r=.199**) and synthesis activities get shorter (r=-0.265**). Moreover, there was no significant correlation between the process output quality and the number of iterations, quality and time, and quality and other process measures. However, the three top designs were generated from a second concept design after scrapping the initial one. The authors conclude that while they generated new insights into the design process, more research (by direct observation) is needed regarding design iterations in industrial projects. About a decade later, Daniel et al (2007) propose a new design approach with a special focus on iterations. They model design as a cyclical process, in which *information gathering* and *evaluation activities* drive *solution refinement*. In a case study, they map the relation between key activities and are thus able to analyse from where solutions originated. Similar to this cyclical process approach formulates Andreasen: "*A loop is characterized by a stop, reflection, partly reformulation/reframing and new efforts, leading to (partly) changed direction and to concretization*" (2015).

Regarding the characteristics, Safoutin (2003) develops a methodology for the empirical measurement of iterations in engineering design processes, distinguishing between *Repetition*, *Progression*, and *Feedback* iterations. Costa & Sobek II (2003) and Costa (2004) propose an iteration classification into *rework* ("repeated activity that changes neither design level nor scope"), *design* ("repeated patterns of activity at a different design level"), and *behavior* ("repeated patterns of activity on different problem scopes"), and suggest that one should eliminate/avoid rework iterations, conduct design iterations at the same level of abstraction, and perform behavioral iterations in parallel. Based on these classifications, Wynn (2007) proposes six non-orthogonal perspectives on iterations: *Exploration* is solution-oriented design problem solving and involves both divergence and convergence of the solution space. *Convergence* occurs when product parameters are selected to meet specific performance objectives. *Refinement* occurs if primary product requirements are met and secondary characteristics can be improved but it is not clearly defined when to stop. *Negotiation* takes place if contributions of several disciplines needs to be integrated to solve a design problem, and trade-offs between different goals need to aligned. *Rework* is necessary if emerging problems drive activities/tasks that were considered complete due to an update of information they were based on. "This is undesirable because effort is expended with no increase in design performance or knowledge." *Repetition* can occur at several points during design to conduct "similar operations to different information." It comprises similar activities aiming at different goals, rather applying different methods to fulfil one (i.e. the same) goal. Moreover, Wynn et al (2007) investigate iterations in engineering design based on these six perspectives and conclude "that process simulation models cannot capture all possibilities for iteration in an [new product development] project".

To summarize, the engineering design perspective provides two approaches to describe iterations, first by defining of what elements iterations consist, and second by characterizing of how they appear. Thus, it would be interesting whether both of these approaches can be integrated and applied *in-situ* on PDPs.

3 Research design

To address our research question '*which characteristics of iterations occur in the fuzzy front end of product development processes?*' we apply an empirical and quantitative research approach, focussing on teams of several companies which are working in their PDPs.

3.1 Research setting

In order to observe and evaluate *in-situ* occurring iterations in the FFE of PDPs, we locate the beginnings of all PDPs in guided ideation workshops at an ideation space in Switzerland. The companies' reasons to start their PDP with such an ideation workshop are manifold, yet prior participating companies evaluated such ideation workshops as promising means for developing

new products, services and business models, and perceived them as an opportunity for enhancing their innovation capability (Heck et al 2015b). The ideation workshops follow the workshop concept by Heck et al (2015c) and comprise the phases of (1) 'identifying the *right* questions', (2) 'identifying promising solutions/answers', and (3) 'getting things done' by preparing the next steps. Each of these phases consists of multiple iterations, in which sub-teams of 3-6 participants conduct specific activities, and then present the other teams their interim results, followed by a feedback session and an evolving discussion.
Thus, we apply the definition of an iterative 'cycle' which begins with a *working session (W)* and ends with a *presentation, feedback, and discussion session (PFD)*, cf. Heck et al (2015a).

3.2 Data sources, sample, and collection

As the ideation workshops are facilitated by experts, we let them *in-situ* characterize and evaluate each iteration based on Wynn (2007)'s iteration characteristic framework (cf. section 2.2.2). This framework was embedded in the *PDP performance reflection guideline*, cf. Heck et al (2016), comprising the dimensions of *input*, *activity*, *output*, *performance rating*, and the *goal for the next iteration*. The cumulated quantitative iteration performance evaluations correlate with the overall workshop performance evaluation from the participants' point of view (Heck et al 2016). Additionally, we observed the conducted ideation workshops and took notes/timestamps during their progresses. We conducted eight 2.5-days ideation workshops, each with another company and its individual design challenge, and observed 122 iterations in total. We conducted and videotaped the structured expert interviews with the facilitators during the workshops and directly after the iterations (while the participants were already working in their next iteration). In total, 107 iterations were evaluated, and it happened that the moderators had to evaluate two iterations at the time, if they had no time during the preceding iteration.

3.3 Data analysis

We followed a two-step data analysis process: First, we extracted the performance ratings and iteration characteristics (in reference to Wynn's 2007 framework and definitions) directly from the videos if they were clearly stated, or coded the characterization if the moderators only described how they characterize an iteration and what the participants actually did (e.g. "divergent thinking" & "ideation" into the characteristic category 'ideation'). From this, a new framework of iterations emerged (section 4.1). Moreover, we extracted the timestamps of iterations and the tasks/activities carried out by the participants from our notes taken during the workshop observations (cf. Figure 1).
Second, we broaden the scope from single iterations to iteration sequences and periods in PDPs. In reference to the concept of divergence/convergence (e.g. Liu et al 2003) and inspired by Mussgnug et al (2015)'s "breathe in, breathe out", we associate the iteration characteristics of *Exploration* and *Ideation* with divergence (i.e. *breathe in*, coded '+1'), the characteristics of *Convergence* and *Consolidation* with convergence (*breathe out*, '–1'), and the characteristics of *Rework*, *Refinement*, and *Negotiation* with neither of them (*hold breath*, '0').

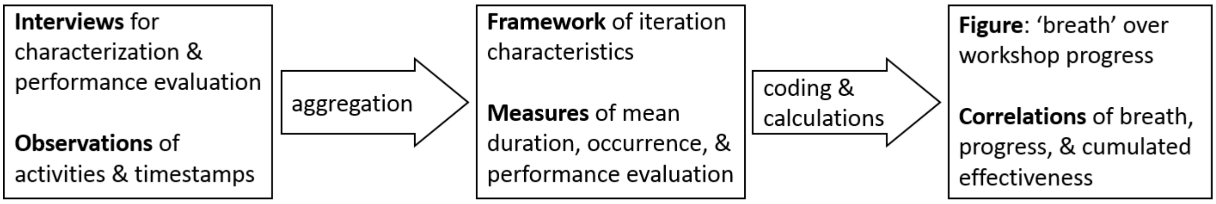

Figure 1. Data structure and results.

4 Results

This section describes in detail each of the iteration characteristics and links them with the applied methods, the provided materials and tools, as well as the emerging team dynamics. For the quantification of the iteration characteristics see Figure 2. Moreover, we code the emerging iteration characteristics, identify three workshop patterns and link them to the overall workshop performance.

4.1 Framework of quantified iteration characteristics in the FFE of PDPs

The following paragraphs describe the iteration characteristics:

Exploration: During the first workshop phase – when the participants try identifying the 'right' problem – they explore the 'problem space' of their design challenge. Drawing an *environment map* supports their understanding of the relevant market, technology related preconditions and challenges, legal aspects, and current customers. Based on the analysis and interpretation of this environment map, they *map out current and future stakeholders* of their business, and identify those who they want to investigate in more detail. Creating *personas and need-finding* is supported by market research and ad hoc interviews. During the second workshop phase – when the participants try identifying promising solutions – they *prototype* their ideated solutions with all kind of materials, to explore the 'solution space' and to learn more about the advantages and obstacles during their application. While the participants are mostly surprised about the problem space complexity during the first phase, they enjoy learning more about their solutions during the second phase. Especially in prototyping sessions some participants get in a state of 'flow'.

Ideation: Once the problem is re-framed and clearly stated, the participants start generating ideas how to overcome this problem. These iterations are characterized by creative and divergent thinking, mostly supported by activities such as *brainstorming* sessions, e.g. *brain walks* around the Castle, and the *visualization/scribbling* of ideas and solution concepts. The participants mostly cannot wait to start thinking-out-of-the-box into the 'solution space'.

Refinement: Especially the second iterations of larger/longer activities (e.g. *need-finding* and *prototyping*) are characterized by refinement, when the most important requirements have been met, but several aspects of the interim results can be modified and improved. This happens during the first and second phase while exploring the problem and solution space, and interim results shall be optimized (e.g. if prototypes were first build with soft materials, and in the next iteration their durability shall be improved with heavier materials). These iterations occur due to the participants' ambition and lead to better interim results.

Rework: Contrarily to refinement, rework iterations occur if the outcome of the previous iteration did not meet the expectations. This happens, e.g. if *user needs* were not understood so that the participants could re-frame the problem statement in the first workshop phase, and in the second if e.g. the *prototypes* did not fulfil the functions they should. Although it is merely frustrating to begin a rework iteration, the outcome is very satisfying (cf. Figure 2).

Negotiation: During the first phase, questions such as "what are we doing here?" or "what to do next?" arise, while such iterations in the third phase are dealing with different priorities regarding project plans or the next steps. These iterations were not intended to be 'negotiation iterations' but became so due to such emerging questions. An open reflection about the status quo and desirable goals leads to valuable discussions and mutual understanding.

Convergence: Convergence iterations occur in all workshop phases, and mostly mark the end of a phase, such as by the formulation of the *problem statement* at the end of phase one, as *preparation of the final presentation* in phase two, or as the *planning of the next steps* in phase three. As the successful completion of a workshop phase is satisfying for the participants, the moderators try to have such convergence iterations at the end of the working days.

Consolidation: These iterations occur only in phase three, when the participants review their most important interim results and decide what ‘to take home’. With the vision what to achieve within the next year by writing the *30Minutes* newspaper article, the participants have a good basis for defining their next steps within the company, i.e. *setting up the next projects*. Moreover, they reflect upon what they have learned and experienced, and how they can communicate that their colleagues who did not participate in the workshop. After these iterations, the participants are on the one hand satisfied with their achievements, and on the other hand exhausted and tired after three days filled with new working approaches, mind sets, methods/tools, and their experience of an ideation journey.

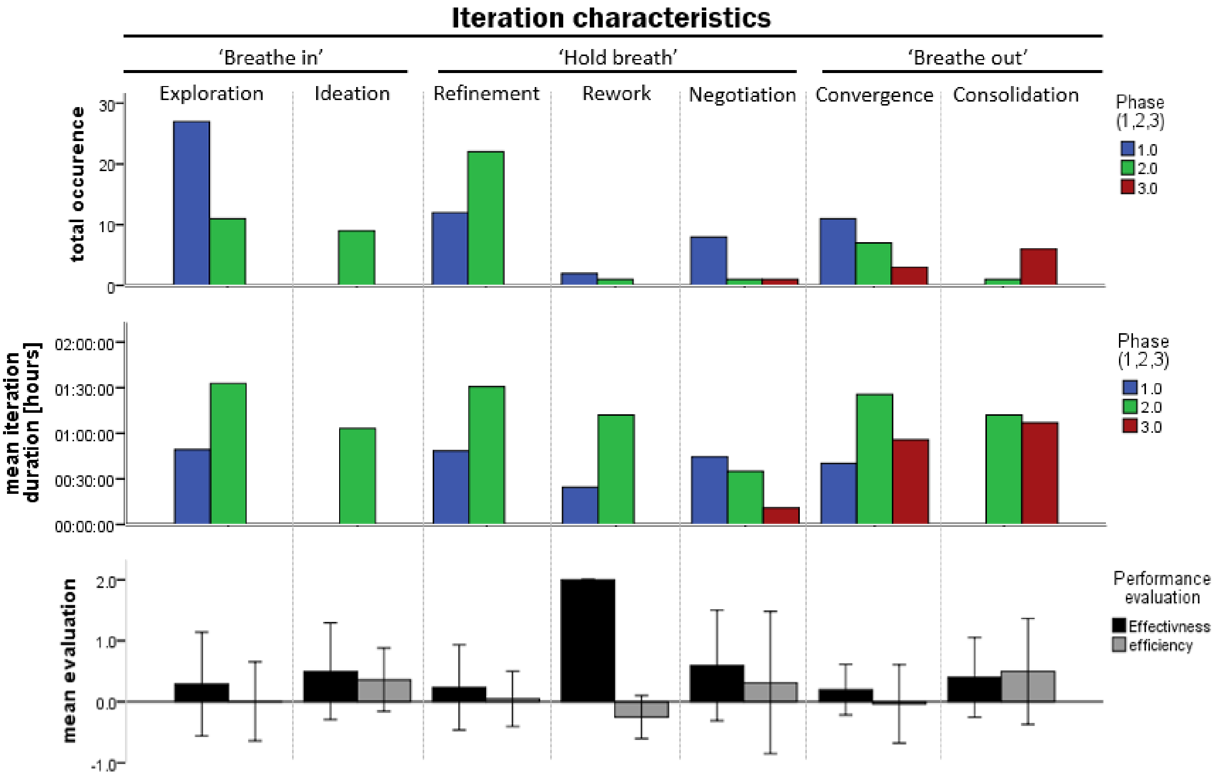

Figure 2. Framework of quantified iteration characteristics.

4.2 Divergent and convergent periods

Based on the ‘breathing’ coding in reference to divergence/convergence (cf. section 3.3), the resulting ‘breath’ cumulates the ‘breathing’ evaluations of each iteration. For instance, with *Exploration* and *Ideation* iterations the ‘breath’ is increasing, and with *Convergence* and *Consolidation* iterations the ‘breath’ is decreasing. Figure 3 plots the ‘breath’ over the workshop progress (i.e. cumulated iterations duration), color-coded with the cumulated effectiveness. Moreover, we show the correlations between the workshop progress, the ‘depth of breath’, and the cumulated effectiveness, classified according to the overall workshop performance.
For the low-performing workshops (cf. Table 1), the correlation between progress and breath is not significant, as well as the correlation between breath and the cumulated effectiveness. However, we find a high negative and strongly significant correlation between the progress and the cumulated effectiveness. For the medium-performing workshops, all three correlations are high and strongly significant. For the high-performing workshops there are medium and strongly significant correlations between progress and breath, and breath and cumulated effectiveness, as well as high and strongly significant correlation between progress and cumulated effectiveness.

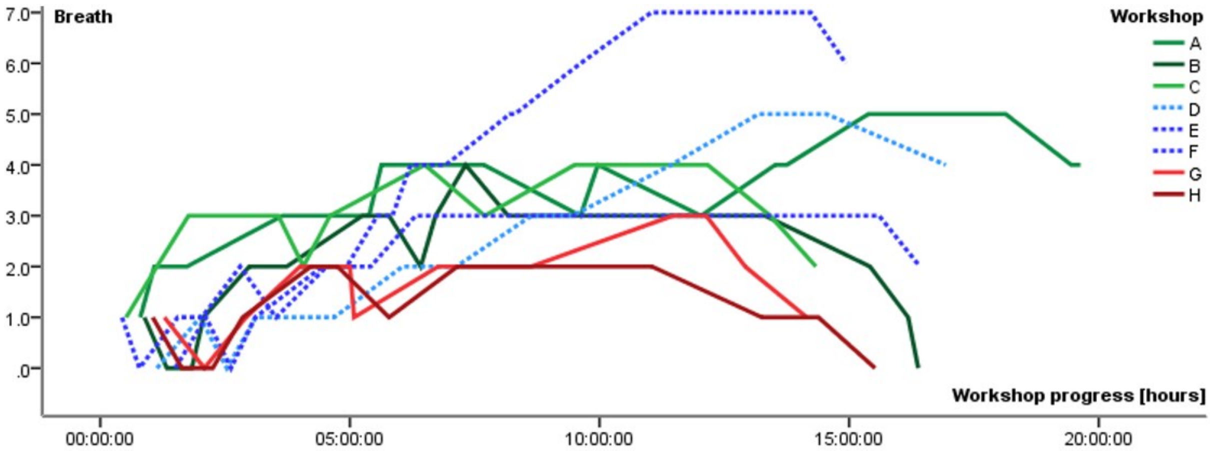

Figure 3. Coded ideation 'breath' (i.e. divergence/convergence) over workshop progress.

Table 1. Correlation of Progress, Breath and E_cum, performance-depending.

	Low-performing WSs (red)			Medium-performing WSs (blue)			High-performing WSs (green)		
	Progress	**Breath**	**E_cum**	**Progress**	**Breath**	**E_cum**	**Progress**	**Breath**	**E_cum**
Progress	1			1			1		
Breath	.284	1		.758**	1		.443**	1	
E_cum	–.506**	–.018	1	.807**	.505**	1	.821**	.414**	1

5 Discussion

Figure 3 illustrates the workshop process. In low-performing workshops (red), the process does almost not breathe. In the medium-performing workshops (blue), the process begins breathing too late and then breathes too much. And in high-performing workshops (green), the workshop process takes a deep breath at the beginning, breathes throughout the workshop progress, and breathes out at the workshop end (i.e. the participants 'nail their results down'). Also the data in Table 1 indicates that the 'breath' is strongly significant correlated with a positive workshop effectiveness, but that 'breathing in' is not the only important activity during the FFE of PDPs. Thus, it seems important to 'breathe in' in the beginning, 'breathe' throughout the process, and 'breathe out' to nail down results at the end of such an ideation workshop.

The iteration methodology by Safoutin (2003) and classification by Costa & Sobek II (2003) and Costa (2004), are at least partially contained in Wynn (2007)'s non-orthogonal perspectives on iterations. However, we identify two additional iteration characteristics (*Ideation* & *Consolidation*) but never explicitly observed *Repetition*. This might be grounded in our applied iteration definition which has – after having conducted several iterations – in itself a repetitive character. Moreover, the occurrence of the iteration characteristics is not equally distributed. *Ideation* occurred only in phase 2, while *Consolidation* was mostly present in phase 3. Furthermore, *Exploration* and *Refinement* were the dominant characteristics, while *Rework* occurred rather seldom. However, *Rework* has by far the highest positive effectiveness evaluation and negative efficiency evaluation. This might be explained with the 'failing' of the prior iteration so that rework was necessary, and that the participants then over-achieved their goal in the second trail.

Even though iterations can occur at any point of time during product development, as well as at different scale, we focused in this study on iterations in the FFE of PDPs. We observed not only expected iterations (Smith & Eppinger 1993) but also provoked iterations (Heck et al 2015a), which might have a positive influence on the PDP performance (Martinez Leon et al 2011, 2013; Kantomaa 2012). Contrary to Smith & Tjandra (1998), we observed (1) discussions throughout the whole workshop progress, (2) an even higher iteration frequency in the beginning of the workshops, and (3) by trend getting longer iteration durations during the workshop progress when the concepts become more elaborate (cf. Figure 2). Moreover, our results show that different iteration characteristics have different performance evaluations. Regarding the descriptions of what an iteration consists, our applied definition of an iterative 'cycle' (i.e. working and presentation/ feedback/discussion) deviates from Daniel et al (2007)'s and Andreasen (2015)'s definitions only in form of a 'phase shifting'.

While our results are derived from the observation of eight ideation workshops with over 120 iterations, the biggest limitation of this approach is the characterisation from only the expert's perspective. Thus, further research could also incorporate the workshop participants' characterisation of the iterations and evaluation of the performance.

6 Conclusion

This research aimed at shedding more light on iterations and addresses the research question '*which characteristics of iterations occur in the fuzzy front end of product development processes?*' By applying an empirical and quantitative research approach with *in-situ* evaluations, we developed a quantified framework of iteration characteristics. Furthermore, we identified effective iteration patterns of divergent and convergent periods, and linked them with the PDP effectiveness. As a theoretical contribution, we highlight the identification of *Ideation* and *Consolidation* as additional iteration characteristics. Moreover, the coding of the characteristics in reference to divergence/convergence, enabled the identification of effective iteration patterns. As a practical implication, these patterns might be beneficial for the coaching of development teams in early phases of PDPs, especially in ideation workshops.

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References

Adams RS, Atman CJ (1999) Cognitive Processes in Iterative Design Behavior. *29th ASEE/IEEE Frontiers in Education Conference*.

Andreasen MM (2015) personal discussion during *SSEDR*, Luxembourg, August 2015.

Costa R, Sobek DK II (2003) Iteration in Engineering Design: inherent and unavoidable or Product of Choices made? *Proceedings of DETC'03*.

Costa R (2004) Productive iteration in Student Engineering Design Projects, Master's thesis, *Montana State University*.

Daniel J, Medland T, Newnes L (2007) Graphical representation of key iterations during the design process, *Proceedings of ICED 2007*, Paris, France.

Drury-Grogan ML (2014) Performance on agile teams: Relating iteration objectives and critical decisions to project management success factors. *Information and Software Technology*, Vol. 56, pp. 506-515.

Ford DN, Sterman JD (2003) Overcoming the 90% Syndrome: Iteration management in Concurrent Development Projects, *Concurrent Engineering*, Vol.11, No.3, pp.177-186.

Heck J, Steinert M, Meboldt M (2015a) Provoking Iterations in Ideation Workshops – an explorative Study. *Proceedings of ICED 2105*, Milan, Italy.

Heck J, Rittiner F, Steinert M, Meboldt M (2015b) Impact Dimensions of Ideation Workshops on the Innovation Capability of SMEs, *Proceedings of CINet 2015*, Stockholm, Sweden.

Heck J, Steinert M, Meboldt M (2015c) Conceptualizing Ideation Workshops for SMEs, *Procedia CIRP 36*, pp. 248-253.
Heck J, Rittiner F, Steinert M, Meboldt M (2016) Iteration-based Performance Measurement in the Fuzzy Front End of PDPs, *Procedia CIRP*, accepted.
Jin Y, Chusilp P (2006) Study of mental iteration in different design situations. *Design Studies*, No. 27, pp. 25-55.
Kanomaa TT (2012) Managing Iterations in Product Development. *Master's thesis, Aalto Uni*.
Krehmer H, Meerkamm H, Wartzack S (2009) The Product's Degree of Maturity as a Measurement for the Efficiency of Design Iterations, *Proceedings of ICED 2009*.
Krehmer H, Meerkamm H, Wartzack S (2010) Avoidance of unnecessary Design Iterations by Monitoring the Product's Degree of Maturity, *Proceedings of DESIGN 2010*, Croatia.
Levardy V, Browning TR (2005) Adaptive Test Process – Designing a Project Plan that Adapts to the State of a Project. *INCOSE*.
Liu YC, Bligh T, Chakrabarti A (2003) Towards an 'ideal' approach for concept generation. *Design Studies*, 24, pp. 341-355.
Martinez C, Farris JA, Letens G (2011) Improving Product Development through Front-Loading and Enhanced Iteration Management. *Proceedings of the 2011 Industrial Engineering Research Conference, Doolen & Van Aken, eds*.
Martinez Leon HC, Farris JA, Letens G (2013a) Improving Product Develoment Performance Through Iteration Front-Loading. *IEEE Transactions on Eng. Mgmt.*, Vol. 60, No. 3,
Martinez Leon HC, Farris JA, Letens G, Hernandez A (2013b) An analytical mgmt framework for NPD processes featuring uncertain iterations. *J Eng Tech Mgmt*, 30, 45-71.
Meboldt M, Mathiesen S, Lohmeyer Q (2012) The Dilemma of Managing Iterations in Time-to-market Development Processes, *Proceedings of MMEP 2012*. Cambridge, UK.
Miller GA, Galanter E, Pribram KH (1965) Plans and the Structure of Behavior. *Holt, Rinehart & Winston, London.*
Mussgnug M, Boes S, Meboldt M (2015) Principles guiding teams in new product development projects, *Proceedings of EPDE 2015*, Loughborough, UK.
Safoutin MJ (2003) A Methodology for Empirical Measurement of Iteration in Engineering Design Processes, *Dissertation at University of Washington*.
Smith RP, Eppinger SD (1993) Characteristics and Models of Iteration in Engineering Design. *International Motor Vehicle Program*, Massachusetts Institute of Technology, 1993.
Smith PR, Eppinger SD (1997) Identifying Controlling Features of Engineering Design Iteration. *Management Science*, Vol. 43, No. 3, pp. 276-293.
Smith RP, Tjandra P (1998) Experimental Observation of Iteration in Engineering Design. *Research in Engineering Design*, No. 10, pp. 107-117.
Unger D, Eppinger S (2011) Improving product development process design: a method for managing information flows, risks, and iteration. *J of Eng. Design*, 22(10), pp. 689-699.
Wynn DC (2007) Model-Based Approaches to Support Process Improvement in Complex Product Development, *PhD-thesis at University of Cambridge*, UK.
Wynn DC, Eckert CM, Clarkson PJ (2007) Modelling iteration in Engineering Design, *Proceedings of ICED 2007*, Paris, France.
Yang Q, Lu T, Yao T, Zhang B (2014a) The impact of uncertainty and ambiguity related to iteration and overlapping on schedule of product development projects. *International Journal of Project Management*, 32, pp. 827-837.
Yang T, Yang Y, Xue CM (2014b) Conflict Analysis between Task Iteration and Design Capabilities in Collaboration Product Development, *International Journal of Security and Its Applications*, Vol. 8, No. 2, pp. 375-386.